Deception Detection using a Task Switching Paradigm:

An Event-Related Potential Study

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Statement of Sources

I declare that this thesis is my own original work and that contributions of others have been duly acknowledged.

Signed: ____Date: ___/___/___

Sarah Williams

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I would like to dedicate this thesis to my father, Ray Williams –

an incredible scientist and one of my inspirations.

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Abstract

Existing methods of lie detection have insufficient accuracy or applicability in forensic settings. The present study aimed to determine whether behavioural and electrophysiological markers of task switching occur when individuals switch between lying and truth telling, as these markers could be used to develop a new method of lie detection, using a modified task switching paradigm. Sixteen participants (five male, aged 18-34) completed a sincerity switching paradigm in which they switched and repeated lying and telling the truth about whether objects were on a previously memorised list. They also completed a comparable traditional task switching paradigm, in which they switched and repeated making environmental and directional judgements about similar objects. In both paradigms, significant switch costs were observed, and a significant ERP negativity occurred at similar latencies in the 500-600 ms post-target interval, on switch relative to repeat trials in a mixed block. The results suggest switching between lying and truth telling does involve task switching processes, and it may be possible to develop a lie detector based on behavioural and electrophysiological markers of sincerity switching. More research is needed to define the conditions under which these markers occur, and to develop a paradigm appropriate for use in forensic settings.

Current lie detection techniques are unreliable, and often based on invalid assumptions or rely on nondiagnostic markers to detect deception (Granhag & Vrij, 2005). However, markers of task switching are robust (Grange & Houghton, 2014). This thesis aims to test whether behavioural and electrophysiological markers of task switching occur when individuals switch between lying and telling the truth, as these could be used to develop a new method of lie detection.

Traditional Approaches to Deception Detection

Traditional methods of deception detection fall into three categories: behavioural observation, verbal analysis, and examining physiological markers (Granhag & Vrij, 2005). Behavioural observation and verbal analysis are unreliable approaches, as no entirely diagnostic behavioural or verbal signs of lying have been discovered (Granhag & Vrij, 2005). A traditional method of using physiological markers to detect deception is the polygraph interrogation technique. The Control Question Technique (CQT) is the most widely used polygraph technique (Meijer & Verschuere, 2015), and involves comparing a suspect's autonomic nervous system response to relevant and control questions. Relevant questions concern the crime under investigation, to which only guilty suspects will lie. Control questions involve lying for all suspects. They are assumed to be true for everyone; but during a pre-interview the examiner deceptively indicates that confessing to these will suggest the suspect committed the crime. An example is "Have you ever hurt someone?" The CQT is based on the assumption that a guilty suspect will show the greatest physiological anxiety response to relevant questions because these relate directly to the crime. In contrast, an innocent suspect will show the greatest response to control questions because for these, they must lie.

The theory underpinning the CQT has come under scrutiny (Meijer & Verschuere, 2015). The fundamental problem is that increased physiological arousal may occur for reasons other than lying, for example, fear of not being believed (Committee to Review the Scientific Evidence on the Polygraph. & National Research Council., 2003). The assumption that control questions are more anxiety provoking for innocents than the directly threatening and potentially emotion-inducing questions about the crime is questionable. This lack of an appropriate control creates high false positive rates (see Table 1), leaving innocent suspects vulnerable to being misclassified as guilty (Meijer & Verschuere, 2015). Another limitation is the established success of countermeasures, which are used to increase responses to control questions (e.g. inflicting pain by biting the tongue) or decrease responses to relevant questions (e.g. by using mental distraction or drugs; British Psychological Society Working Party, 2004), making a guilty suspect appear innocent.

The Guilty Knowledge Test and P300 GKT

The Guilty Knowledge Technique (GKT) was developed to overcome some limitations of the CQT, and focuses on detecting signs of recognition in response to objects or details of a crime (Meijer & Verschuere, 2015). The assumption is that only a guilty suspect possesses “guilty knowledge” of these details, causing them to exhibit an orienting reflex (a detectable pattern of physiological responses when stimuli are perceived as significant or different) on detail presentation (Meijer & Verschuere, 2015). Suspects are presented with plausible alternatives to crime-related questions, and provide a denial response to each. Guilty suspects are expected to display an orienting reflex to the correct alternative (the ‘probe’) due to its salience for them. Innocent suspects are expected to display equivalent responses to

Table 1

Estimated Accuracy Rates (%) of Current Lie Detection Techniques

	TP	**FN**	TN	**FP**	Type of studies	*N* of studies	Reference
CQT	74-82	7-8	61-83	10-16	Laboratory	4	(Meijer & Verschuere, 2015)
	84-89	1-13	59-75	5-29	Field	3	(Meijer & Verschuere, 2015)
	55-72	1-17	83-88	12-47	Review articles of field studies	7	(British Psychological Society Working Party, 2004; Granhag & Vrij, 2005)
GKT	76-88	12-24	83-97	3-17	Laboratory	4	(Meijer & Verschuere, 2015)
	42-76	24-58	94-98	2-6	Field	2	(British Psychological Society Working Party, 2004; Granhag & Vrij, 2005; Meijer & Verschuere, 2015)

Notes: Rates do not always add up to 100% due to a number of inconclusive results. TP = True positive rate, FN = False negative rate, TN = True negative rate, FP = False positive rate.

probes and incorrect alternatives (‘foils’), as they are unable to differentiate between the two. Recently, the GKT has been coupled with ERP measures in an attempt to achieve higher accuracy. In particular, the P300 component has been investigated, as its amplitude is modulated by recognition, rarity, and meaningfulness of stimuli (Iacono, Allen, Rosenfeld, & Lorig, 2002). Guilty suspects are expected to show an enhanced P300 response to probes (Iacono et al., 2002). An advantage of the P300 GKT is that the rapid onset of the P300 response (peaking at 500-600ms post-stimulus in the P300 GKT), and the requirement of speeded responses make countermeasures detectable or difficult to attempt (Iacono et al., 2002).

There are a number of drawbacks of the GKT, meaning it is hardly used in field settings (Meijer & Verschuere, 2015). It cannot be used in many situations, such as when individuals other than the offender and police know details about the crime. Examples include if the suspect was present when the crime took place (e.g. as a witness, or in sexual assault cases where consent is contested), or if lawyers, investigators or the media have made crime details available to the suspect. Another drawback is that it is plausible for a suspect to exhibit an orienting reflex or enhanced P300 to crime-relevant details when they are not guilty, for example, if the murder weapon is a gun and the innocent suspect owns an unregistered gun (British Psychological Society Working Party, 2004). An offender may also fail to exhibit an enhanced response for reasons such as forgetting crime details (e.g. if it happened long ago or they were intoxicated), or not knowing them to begin with (e.g. failing to notice the colour of the victim's shirt; Mertens, 2006). Consequently, estimates of false negative rates for the GKT are high (see Table 1), leading to a high risk of incorrect exoneration. As a result of the limitations of established lie detection techniques, new research has begun to explore other possible methods, such as cognitive load approaches.

Cognitive Load Approaches to Deception Detection

Cognitive load approaches use techniques designed to increase the cognitive load imposed on deceivers, and use signs of this heightened load (such as slowed response times) to distinguish them from truth-tellers (Walczyk, Igou, Dixon, & Tcholakian, 2013). The core assumption of this approach is that lying in a high stakes situation is cognitively more difficult than telling the truth (Vrij, 2015). Liars must formulate and monitor their lies, create a credible impression, and monitor an interviewer's reactions, whereas truth-tellers do not experience many of these extra cognitive demands (Vrij, 2015). Imposing additional cognitive load on liars, who already have fewer remaining cognitive resources, means they should not be as capable of coping with these extra demands (Vrij, 2015). Ways of increasing cognitive load include having suspects retell events in reverse order, or asking unanticipated questions (Walczyk et al., 2013).

However, it has been questioned whether all lying is indeed more difficult than remembering and recounting events during a high stakes interview. For example, Van Bockstaele, Wilhelm, Meijer, Debey, and Verschuere (2015) found that the cognitive cost of lying (indexed by slowed response times and increased errors) reduces when individuals respond deceptively more often than truthfully, an effect they labelled the 'truth proportion effect'. This suggests that well-practised liars may be difficult to differentiate from truth-tellers using cognitive load techniques. Of particular interest to the present study, Van Bockstaele et al. (2015) suggested switch costs may present a confound in studies examining the truth proportion effect. In designs with frequent lie trials, truth trials are more likely to involve a switch from a lie to a truth trial, whereas lie trials are more likely to involve a repeat. To control for response time costs suspected to occur due to task switching, they analysed only trials in which participants switched from responding truthfully to deceptively, or vice versa. They found that controlling for switch effects caused the truth proportion effect to reduce. This suggests that switching between truth telling and lying may indeed involve task switching processes, as switch costs influenced the manifestation of the truth proportion effect.

The Task Switching Paradigm

Task switching paradigms have been designed to investigate cognitive control processes involved in switching between tasks (Grange & Houghton, 2014). These paradigms require participants to repeat and switch between performing two (or more) simple tasks (see Figure 1). Paradigms commonly involve pure and mixed blocks (Meiran, 2014). Mixed blocks include repeat trials, in which the task performed on the current trial is the same as that of the previous trial, and switch trials, in which the current task is different to the previous trial. In pure blocks only one task is completed, so every trial is a repeat trial.

Mixed blocks enable investigation of differences between repeat and switch trials while the load on working memory is held constant, as both sets of task instructions are held in memory during this block. Only one set is held in memory during the pure block, creating a differential working memory load between blocks (Grange & Houghton, 2014; Rogers & Monsell, 1995). Mixed block repeat trials may also be compared to pure block repeat trials to examine this differential memory load, although differences may also reflect differential levels of arousal or effort between blocks (Rogers & Monsell, 1995). Additionally, pure blocks may be used to check that effects observed in the mixed block are not simply a result of changing target stimulus type, or cue.

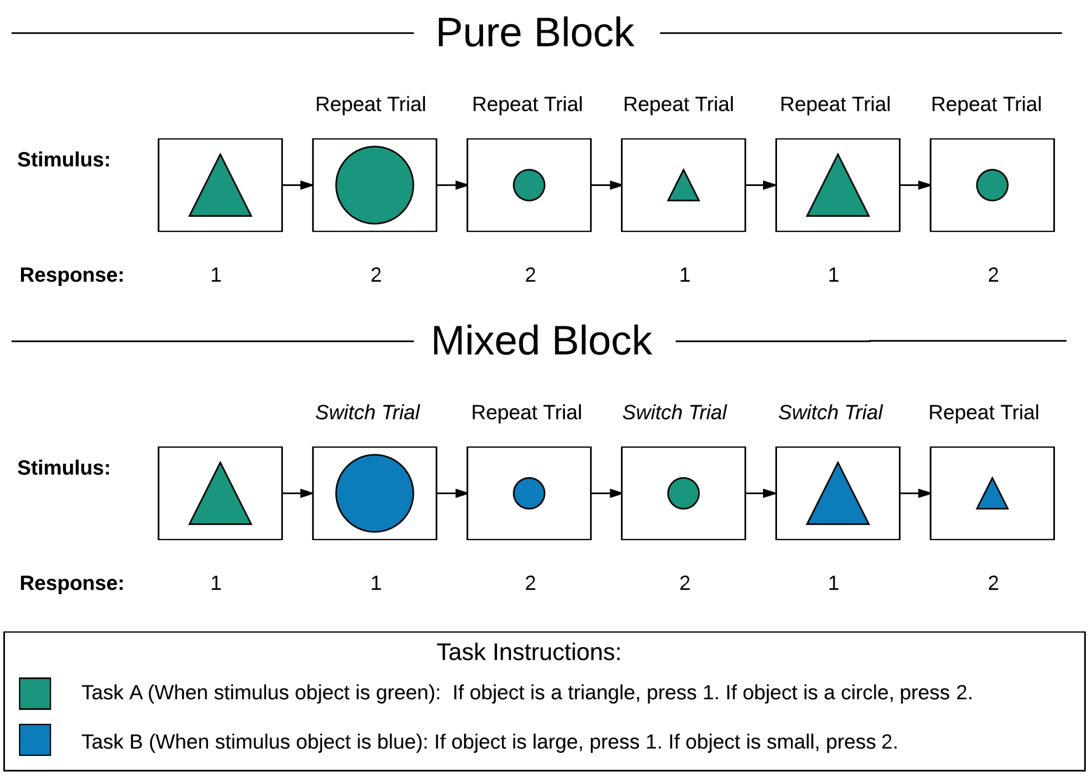

Figure 1. Schematic of a Task Switching Paradigm.

Cued task switching paradigms involve presenting a visual cue before the target to indicate which task to complete. Paradigms may also be uncued, and may involve completing tasks according to a memorised sequence, or choosing tasks voluntarily (Grange & Houghton, 2014). A dimension of the target, such as its position or colour, may also be used to signify task (Dreisbach, Goschke, & Haider, 2007; Swainson, Jackson, & Jackson, 2006).

Despite the variability of paradigm designs, findings have been similar and robust (Grange & Houghton, 2014). During mixed blocks, response times on switch trials are slower than on repeat trials (Grange & Houghton, 2014; Jamadar, Thienel,

& Karayanidis, 2015; Kiesel et al., 2010). This finding is termed the *switch cost*. Switch costs have been replicated in both cued and uncued paradigms (Swainson et al., 2006), when stimuli are words (e.g. Dreisbach et al., 2007), or images (e.g. Karayanidis et al., 2006), when stimuli are externally or internally generated (Dumontheil, Gilbert, Burgess, & Otten, 2010), and even when a task switch involves a simple reversing of response key mappings (referred to as *response switching*; Rushworth, Passingham, & Nobre, 2002). Switch costs are also observed when target stimuli are univalent (each target affords just one task; Karayanidis et al., 2006), or bivalent (either task could be performed on each target; Jamadar et al., 2015), and when responses are univalent (different response key sets are used for different tasks), or bivalent (the same response keys change their meaning depending on the current task; Mueller, Swainson, & Jackson, 2007), although switch costs are often greater when bivalent targets and responses are used (Jamadar et al., 2015). Manipulating the time participants have to prepare for an upcoming switch also affects response times, as longer preparation intervals reduce (but do not eliminate) switch costs (Jamadar et al., 2015).

Electrophysiological Markers of Task Switching

Electrophysiological differences have also been observed between mixed block repeat and switch trials. The event-related potential (ERP) technique is a method of using electrodes to record electrical activity from the scalp, then averaging all activity locked to a repeated stimulus category to measure the brain's electrical response to that stimulus (Luck, 2014). The ERP method has been used to investigate cognitive control mechanisms involved in task switching due to its high temporal resolution (Karayanidis & Jamadar, 2014). Two findings have been predominant. Firstly, a late, sustained *switch positivity* is observed after a task switch has been cued, compared to when a repeat is cued (Jamadar et al., 2015; Karayanidis & Jamadar, 2014). The switch positivity peaks at around 400-600ms after cue onset, is maximal over parietal electrodes, and is thought to be generated in the posterior parietal cortex (Karayanidis & Jamadar, 2014). Secondly, on presentation of a target stimulus on which a new task is to be performed, a late, sustained centroparietal *switch negativity* is observed, compared to on repeat trials (Jamadar et al., 2015; Karayanidis & Jamadar, 2014). This switch negativity is thought to originate in the left cingulate cortex, although it has also been correlated with activity in the anterior cingulate and right posterior parietal cortices (Jamadar et al., 2015; Karayanidis & Jamadar, 2014). When the target is preceded by an informative cue and long preparation interval, the switch negativity peaks at around 600ms post-target (Karayanidis & Jamadar, 2014). When cues are noninformative, when the target and cue are presented simultaneously, or when one element of the target (such as its colour) acts as a cue, the switch positivity occurs after the *target* and the switch negativity is delayed until the positivity resolves (Jamadar et al., 2015; Swainson et al., 2006).

Theories of Task Switching Processes

There are two dominant theories proposed to explain the costs associated with switching between tasks: task set inertia and task set reconfiguration. A *task set* is a mental representation of the parameters and processes required to carry out a task (Schneider & Logan, 2014). Allport, Styles, and Hsieh (1994) hypothesised that switch costs occur because activation of the task set from the preceding trial carries over to the current trial. Although this activation is still relevant on repeat trials, switch trials require activation of a different task set. In addition, on switch (but not repeat) trials, the currently relevant task set was inhibited on the previous trial, and this inhibition is still active. Task-irrelevant activations and inhibitions dissipate over time (Allport et. al., 1994, argue for a timeframe of about a minute), however, when trials change rapidly, dissipation is not yet complete, creating ‘task set inertia’ (Allport et al., 1994). According to this theory, switch costs reflect the time taken to resolve interference caused by enduring task-irrelevant activations and inhibitions, and longer preparation intervals allow greater dissipation time, thereby reducing switch costs.

Support for task set inertia theory comes from the observation of asymmetric switch costs when tasks are of uneven difficulty. Perhaps counter-intuitively, switch costs are often greater when switching from a difficult to an easy task, compared with switching from an easy to a difficult task (Allport et al., 1994; Schneider & Anderson, 2010). This phenomenon is explained by task set inertia. On difficult task trials, strong inhibition of the easy (more dominant and easily activated) task, and strong activation of the difficult (less dominant) task are required. Both persist to the next trial, on which the easy task must be performed. Increased time is required to resolve this strong counterproductive inertia. In addition, easy task trials require less activation of the easy task, and less inhibition of the difficult task, so less counterproductive inertia is carried over to difficult trials, causing switch costs to reduce (Allport et al., 1994).

In contrast to the passive dissipation processes of task set inertia theory, Rogers and Monsell (1995) hypothesised that switch costs reflect the time course of an active process of mental task set reconfiguration. This process involves the cognitive system updating the current task set to align with the newly relevant task goals. According to this theory, reductions in switch costs at longer preparation intervals occur because task sets have had more time to reconfigure. In support of their theory and in opposition to task set inertia theory, Rogers and Monsell (1995) found that switch costs improve on the next repeat trial, but no further improvement is observed on the third or fourth repeats after a switch. Task set inertia theory suggests that response times would continue to improve on consecutive repeat trials, as inertia has had more time to dissipate. However, if task sets have fully reconfigured on the first switch trial, performance improvements on the second and third repeat trials would not be expected (Rogers & Monsell, 1995).

Task set reconfiguration is thought to begin once a task switch is signalled, whereas task set inertia is thought to begin dissipating once the previous trial has ended. The cued task switching paradigm was originally created to test these competing hypotheses by separating out the processes of reconfiguration from inertia (Grange & Houghton, 2014). If the interval between the previous response and current cue is varied while the interval between the cue and target is held constant, persisting task set inertia is manipulated, while task set reconfiguration time is held constant. In contrast, if the cue-target interval is varied while the interval between the previous response and the target is held constant, reconfiguration time is manipulated while inertia is held constant. In fact, both of these variations affect switch costs, suggesting that both processes are involved (Grange & Houghton, 2014). Also, if intervals are lengthened enough that time benefits for both inertia and reconfiguration reach asymptote, a residual switch cost still remains (Grange & Houghton, 2014; Meiran, Chorev, & Sapir, 2000). This suggests a third component, occurring after presentation of the target, is involved in task switching (Grange & Houghton, 2014; Meiran et al., 2000).

ERP studies support the notion that there are multiple processes involved in task switching. Cue-locked ERPs are able to investigate cognitive processes involved in preparing for an upcoming switch (such as task set reconfiguration), and typically observe the switch positivity (Karayanidis & Jamadar, 2014). Target-locked ERPs are able to examine the reactive control processes occurring after target presentation, such as resolution of target-driven interference, and this is when the switch negativity typically occurs (Karayanidis & Jamadar, 2014). As the switch positivity typically occurs post-target when the target signals which task to perform, this suggests it reflects task-set reconfiguration, as it occurs after a switch has been signalled, even if this happens at differing time points (i.e. after cue or target presentation; Jamadar et al., 2015). The components of the switch negativity are thought to reflect greater carryover or target-driven interference on switch trials, and the greater need for reactive control processes to overcome this interference (Karayanidis & Jamadar, 2014).

Task switching processes are thought to occur whenever it is necessary to switch to performing a new task (Grange & Houghton, 2014). Therefore, it may be possible that these processes will occur when an individual switches between lying and telling the truth, creating switch costs and ERP differences. If they do occur, these "sincerity switching" costs and ERP differences, as they will be referred to, could be used as the basis for a new method of deception detection.

Task Switching in a Deception Context

A thorough literature search revealed that the idea of using task switching processes to detect deception has been mentioned once before. Debey, Liefooghe, De Houwer, and Verschuere (2015) investigated whether the cognitive costs of lying often found in behavioural data (reflected in slower and less accurate performance on trials requiring deceptive compared to truthful responses) could be attributed to asymmetric switch costs that may emerge in lie detection studies when participants switched from lying to telling the truth and vice versa in the same block. These asymmetrical switch costs could cause lying to appear to be more cognitively difficult than truth-telling when in fact it is the *switch* to lying that is more difficult than the switch to truth-telling. Debey et al. (2015) asked participants to respond truthfully or deceptively to yes-no questions about activities they had performed in the lab, and to autobiographical questions. The colour in which the questions were presented (yellow or blue) signified whether to lie or tell the truth. They found that, as the costs of switching from lying to telling the truth and vice versa were symmetrical, behavioural costs on lie trials in balanced designs (with equal numbers of lie and truth switch trials) could not be attributed to asymmetrical switch costs. Importantly though, they did find a behavioural switch cost, as switching between lying and truth telling resulted in increased response times compared to repeating one of the two. Debey et al. (2015) argue that this switch cost could distort the findings of paradigms examining the cognitive cost of lying, if lie and truth trials are not balanced over switches and repetitions. They also suggest that unbalanced designs could be used strategically to increase the cognitive cost of lying, making it easier to detect. The present study expands on this idea in that it suggests that both behavioural and electrophysiological markers of task switching may be used to detect lying in paradigms in which guilty individuals (but not innocents) must switch between responding truthfully (to questions with known answers) and responding deceptively (to questions about the crime).

Rationale, Aim and Hypotheses

As stakes are high in forensic contexts, it is crucial to use valid and highly reliable methods of detecting deception in criminal investigations. However, current methods rely on flawed theories or have severe limitations. The aim of this study is to replicate switch costs, and determine whether switch-related ERPs occur, when a person switches between responding truthfully and responding deceptively, as knowledge of these could lead to the development of a new method of lie detection, using a modified task switching paradigm. If this procedure were to be successful, it would not rely on detecting nondiagnostic signs of lying such as increased arousal or cognitive load (both of which may be increased or reduced due to factors other than deception), nor would it rely on an orienting or recognition response, which may be elicited or fail to occur due to factors other than guilt or innocence. Rather, it would rely on detecting the specific signs of sincerity switching to determine whether an individual is responding truthfully to all questions, or if, on crime questions, they are answering deceptively. Response times are susceptible to countermeasures, (Rosenfeld, Soskins, Bosh, & Ryan, 2004; Walczyk et al., 2013), but if ERP markers of task switching are produced when individuals switch between lying and telling the truth, combining the ERP method with behavioural measures to detect task switching in a speeded paradigm could make it difficult to use countermeasures against a "sincerity switching lie detector".

While it was considered that a switch negativity could occur following a switch positivity in the current paradigm, the positivity is the focus of the ERP hypotheses, as target colour is used to signal task, and the positivity has been found to occur after the target when preparation intervals are short (Jamadar et al., 2015; Karayanidis et al., 2006), or non-existent (e.g. Swainson et al., 2006, found a positivity but no negativity when target colour signified task). Also, as the switch positivity is thought to resolve before any negativity occurs (Jamadar et al., 2015), the timing of a delayed switch negativity would be difficult to predict using the current paradigm.

In a traditional task switching paradigm, it is hypothesised that, during a mixed block, response times will be significantly greater, and ERP amplitudes at parietal electrode site Pz significantly higher around 400-600 ms post-target, when participants switch from performing a directional classification task (i.e. is the object facing left?) to an environmental classification task (i.e. is this an indoors object?) and vice versa compared to when they repeat a task, demonstrating a switch cost and switch positivity. As a validity check, it is hypothesised that switch costs will be significantly greater than any response time difference that may occur between changing and repeating target colour during a pure block in which no task switches occur.

Crucially, in a 'sincerity switching' paradigm in which participants repeat and switch between lying and telling the truth, it is hypothesised that, during a mixed block when participants are asked if a target stimulus is a member of a previously memorised list, response times will be significantly greater, and ERP amplitudes at Pz significantly higher (in a similar time period to the traditional paradigm), when participants switch from responding truthfully to responding deceptively, and vice versa, compared to when they repeat one of these sincerity tasks. It is also hypothesised that switch costs will be greater than any response time difference observed between changing and repeating target colour during a pure block in which participants only tell the truth.

Method

Participants

An a priori power calculation using G*Power indicated that 24 participants would be required to detect a moderate sized effect (f=.25) with a power of 0.8 at α=.05. A medium effect size was used in this power calculation as medium effects are often observed in behavioural task switching studies (e.g. Lange, Seer, Muller, & Kopp, 2015; Schneider & Anderson, 2010), and a small effect may have questionable utility for the development of a lie detection technique. Twenty participants were recruited, although four participants were excluded from analyses (three due to equipment faults, one due to achieving below 70% accuracy during an experimental block). The final sample consisted of 16 participants (five male, aged 18-34, $M = 24.1$, $SD = 5.5$), seven of which were psychology undergraduate students receiving course credit for participation. Participants were recruited via advertisements on noticeboards at the University of Tasmania, on the Division of Psychology research participation website and on social media. Interested individuals were directed to an online screening questionnaire, from which eligible volunteers were contacted.

All participants were right-handed with normal or corrected-to-normal vision and hearing. They were excluded if they had a history of neurological, sleep or psychiatric (other than anxiety and affective) disorders, severe head injury, or epilepsy. Other exclusion criteria were heavy alcohol use and heavy and recent illicit drug use (greater than 10 lifetime occasions or use in the last 6 months). Participants were also excluded if they were currently taking prescription drugs other than SSRIs (n=4) or contraceptive medication (n=1). Participants spoke English as a first language, and multilinguals were excluded as they show improved task switching capabilities due to experience in switching between languages (Prior & MacWhinney, 2010). Participants refrained from alcohol for the 24 hours prior to participation, and from illicit substances since screening. The study was approved by the Tasmanian Social Sciences Human Research Ethics Committee (Appendix A).

Materials and Apparatus

Stimuli and Stimulus Groups. The stimuli were 80 line drawings of common objects (see Appendix B), 40 used in the sincerity switching paradigm and 40 in the traditional task switching paradigm. These stimuli were developed by the researcher in order to control for simplicity, colour, memorability, and emotional valence, and to ensure there were sufficient unique images with common bivalent attributes. A pilot study was conducted in which 17 participants rated 96 images in terms of valence (-3 to +3 point scale) and arousal (0 to 6). Participants also rated the recognisability of each image, and how strongly they perceived each as an indoor or outdoor object. All objects chosen were highly recognisable, and the objects used in the traditional switching paradigm were classified as either strongly indoors or outdoors.

For the sincerity switching paradigm, 20 objects were randomly assigned to 'List A', and 20 to a list called 'Other objects presented during the task' (referred to hereafter as 'Other Objects'; see Appendix B). They were presented during the paradigm in either green (50% from each list, randomly assigned) or blue. Ratings from the pilot study indicated no significant differences in valence or arousal ratings between lists or colour groups (see Table 2).

The stimuli used in the traditional paradigm had two attributes: they were most commonly used either indoors (50%) or outdoors, and were either facing left (50%) or not facing left (i.e. facing forward or right; see Appendix B). These attributes are referred to as 'environment' and 'direction'. There were 20 objects in each attribute category, and 10 objects for each of the four attribute combinations (e.g. indoors, facing left). Objects were also presented during the paradigm in either green or blue (50% from each combination; randomly assigned). There were no significant differences in valence or arousal ratings between the two environment, direction, or colour groups (see Table 2).

Table 2

Comparisons of Valence and Arousal Ratings for Targets Across Classification Type

Classification Type	Valence		Arousal	
	F	p	F	p
Sincerity Paradigm				
List	2.00	.18	0.33	.57
Colour	7.64	.014	0.12	.73
Traditional Paradigm				
Environment	1.19	.19	5.50	.03
Direction	0.24	.63	0.20	.66
Colour	0.78	.39	0.45	.51

Notes. Degrees of freedom are 1, 16 for all. Bonferroni corrected $\alpha = 0.012$.

Stimuli Lists and Paper Tasks. Six lists of 20 stimuli were used in this study (see Appendix B). For the sincerity switching paradigm, two lists were used to memorise objects (List A, Other Objects). For the traditional paradigm, four lists were used to verify that participants agreed with each objects' assigned attributes ('Indoors Objects', 'Outdoors Objects', 'Facing Left', 'NOT Facing Left'). Combined, the two environment lists presented the same 40 objects as the two direction lists, but categorised by environment rather than direction. The objects on each list were presented in black in a 4 by 5 array at 4.5×4.5cm.

Paper Task A verified that participants had memorised the objects on List A. This involved quizzes in which the 40 targets used in this paradigm were presented in random order (at 4.5×4.5cm, 10 per page). Participants wrote an 'A' next to each image that was on List A, and a dash next to each that was not (i.e. those on the Other Objects list). All of the 40 objects were presented in these quizzes in an attempt to equate any ERP recognition responses produced by the targets during the experimental task (e.g. an increased P300 component; Fabiani, Gratton, & Federmeier, 2007). This task concluded once two consecutive quizzes were completed with 100% accuracy.

In the traditional paradigm, participants completed Paper Task B before commencing their first block to make the two paradigms as similar as possible, to verify that participants could categorise the objects correctly, and in an attempt to equate any ERP recognition responses. This task involved completing quizzes in which the 40 targets used in this paradigm were presented in random order (at 4.5×4.5cm, 10 to a page). Participants recorded whether each object was an indoor or outdoor object on the first quiz (by writing an 'I' or 'O' next to the image), then whether each object was left facing or not left facing ('L' or 'N'). Achieving 100% accuracy on both quizzes concluded Paper Task B.

Task Switching Paradigms. The two paradigms were completed on computer using STIM^2 software. Before each block, on-screen instructions appeared and participants completed 16 practice trials (8 switch trials, ordered pseudorandomly) prior to the true experimental trials.

In the sincerity switching paradigm, knowledge of the images on List A was used as a substitute for knowledge of involvement in a crime, as in each of these situations, the truth is has been stored and can be accessed from memory. In the pure block of this paradigm, instructions were to respond to the yes-no question 'Was this object on List A?' In the mixed block, instructions were to answer the same question, however, participants were instructed to lie if the object was blue (counterbalanced between subjects with green). In the traditional paradigm pure block, instructions were to answer the question 'Is this object left-facing?' In the mixed block, participants answered this same question, unless the object was blue (counterbalanced with green), in which case they answered the question 'Is this an indoors object?' Colour was used to signify task rules in these paradigms in order to mimic the simultaneity of target presentation and task information that would occur when a suspect is presented crime and non-crime questions. In both situations, an aspect of the question, or target itself signifies whether to lie or tell the truth.

Each block consisted of 160 true experimental trials, 80 of which were switch trials, and took 10-15 minutes to complete. Trials were pseudorandomly ordered so that all previous-to-current trial types were balanced (see Appendix C for details). Each trial began with a white fixation cross presented for 2000-3000ms (jittered in multiples of 100). Subsequently, a 7cm×7cm target stimulus was presented until a response was made (or for 4000ms maximum). The next trial then began. Each image was presented either eight or nine times during a paradigm, and no image was repeated on consecutive trials. Participants sat approximately one metre from the screen and made responses by pressing buttons labelled 'YES' and 'NO' with the first and second fingers of their right (dominant) hand. At the end of each block, participants completed a task questionnaire (see Appendix D), which included a subjective units of distress scale, a task difficulty rating scale, and a qualitative question probing participants' experience of each block, in the hope of revealing strategies that may be used, particularly in the sincerity paradigm.

Electrophysiological Recording. A NeuroSCAN system and 32-channel Quik-Caps with Ag/AgCl sintered electrodes were used to measure electrical activity from the scalp. EEG data was recorded continuously from 32 sites, positioned according to the 10-20 system of electrode placement. Electrodes were referenced to linked mastoids and impedances were kept below 10kΩ. Electrodes placed above and below the left eye, and on the outer canthi of both eyes recorded vertical and horizontal electro-occulographic activity. Data was sampled continuously at a rate of 1000Hz, and was averaged over a 1000ms epoch commencing 100 ms before target presentation.

During the editing phase, behavioural and continuous EEG data were merged. The EEG data were filtered using a Zero-phase-shift low-pass filter (30Hz, 24dB/Oct), and ocular artefact reduction was conducted to reduce eye blinks artefacts. An artefact rejection set at ±70 µV was also applied. Extracted epochs of -100 to 900ms post target onset were used to create the individual average waveforms used in the ERP analysis, with automated baseline correction during the pre-target interval.

Procedure

See Figure 2 for a flowchart of the procedure. Participants first read an information sheet (Appendix E), then provided their informed consent (Appendix F). They then completed an experimental session screening questionnaire to confirm their eligibility to participate (Appendix G) The entire session lasted a maximum of three hours. The order of the paradigms, as well as the order of the pure and mixed blocks within them, was counterbalanced. Order effects were also mitigated by discarding the first 16 practice trials of each block, as Meiran (2014) suggests.

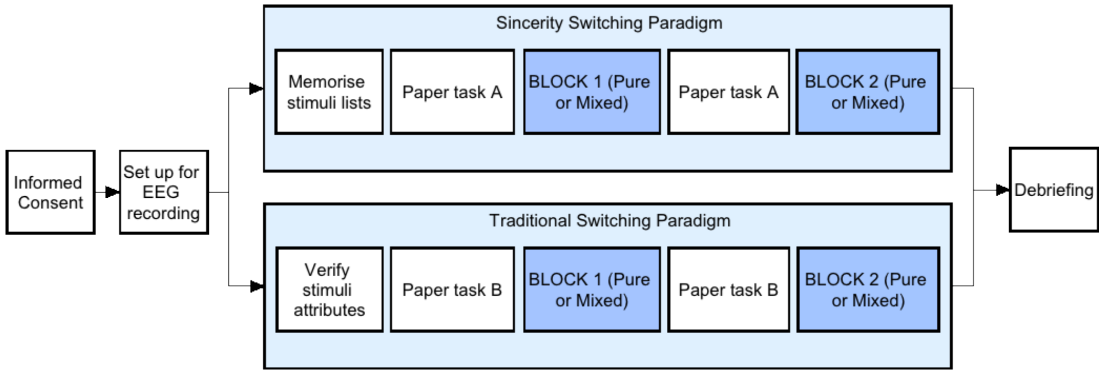

Figure 2. Flow Chart of the Experimental Procedure.

Before completing the sincerity paradigm, participants were given List A, the Other Objects list, and three pieces of blank paper to use to help memorise List A. Participants were asked to take as much time as they needed to memorise the List A objects, were advised they were not being timed, and that the blank paper would be taken away after the memorising period. When participants indicated they were ready, they completed Paper Task A and the sincerity paradigm experimental blocks. Paper Task A was completed again between blocks, so any mistakes participants were making could be corrected, and to mitigate carryover effects by reducing the activation/priming of the first block's task instructions.

Before completing the traditional paradigm, participants were given the lists of indoor, outdoor, left facing, and non-left facing objects. They were asked to name each object (to ensure that they looked at each one), and to verify they agreed with the category it was placed in. They then completed Paper Task B and the traditional paradigm experimental blocks. Similar to the sincerity paradigm, Paper Task B was completed once more between blocks, so mistakes could be corrected and to mitigate carryover effects.

Between blocks, participants were offered a self-paced break. After each block, participants completed the task questionnaire. On conclusion of the experiment participants were fully debriefed, offered a novelty brain magnet for their participation, and thanked for their time.

Design and Data Analysis

Participants whose data were incomplete (n=3), and who achieved below 70% accuracy (n=1) were excluded from analyses. Also excluded were trials with response times below 100ms or three SDs above that participant's mean, the first trial of each block, and trials in which incorrect responses were made. Assumptions for each test were checked to ensure analyses performed were appropriate for the data. In pure blocks, trials that involved a stimulus colour change are referred to as 'change' trials.

For the behavioural data, two 2×2×2 repeated measures ANOVAs were conducted to examine the effects of Paradigm (Sincerity, Traditional), Block (Pure, Mixed), and Trial Type (Repeat, Switch/Change) on response time and accuracy. A separate 2(Block) x 2(Trial Type) repeated-measures ANOVA for each paradigm was planned to clarify a significant second order interaction, followed by two ANOVAs to clarify simple effects of trial type within each block. A Bonferroni adjustment was made to the alpha level to control the Type I error rate. Partial eta^2 was used as a measure of effect size for omnibus effects, and Hedges' *g* for simple and main effects, as this statistic is appropriate for use in small sample sizes (Turner III & Berardi, 2006).

For electrophysiological data, grand averaged waveforms were created for switch and repeat trials from mixed blocks, and change and repeat trials from pure blocks of the sincerity and traditional paradigms. To identify periods of significant difference between mixed block switch and repeat waveforms, *t*-tests were conducted on means of 5-millisecond mini-epochs along the ERP waveform across the interval of 500 and 600ms post-target. A criterion of consecutive significance was used whereby a run was considered significant when two consecutive tests produced a significant difference, and ceased to be significant once two consecutive tests failed to reach significance. Rugg, Doyle, and Melan (1993) first used this technique for comparing late onset waveforms, and it has since been used to compare task switching ERPs (e.g. Jackson, Swainson, Cunnington, & Jackson, 2001; Mueller et al., 2007; Rushworth et al., 2002; Swainson et al., 2003; Swainson et al., 2006), because switch differences have not been isolated to a single component (multiple components are likely involved; Karayanidis & Jamadar, 2014). While the criterion is arbitrary, many studies use a criterion of 10 and test smaller mini-epochs than the current study, testing along the entire waveform. The a priori criterion of two was chosen for this study as the mini-epochs used were comparably large and only a small waveform interval was chosen for analysis, considerably reducing the number of tests conducted in comparison to previous literature. The 500-600ms time period was chosen based on previous findings that task switching effects occur around this period (Karayanidis & Jamadar, 2014), and based on differences observed in the grand averaged waveforms between switch and repeat conditions in the mixed (but not pure) blocks. While a positivity was originally hypothesised, it was a negativity that appeared to occur. However, analyses required no adjustment as the negativity appeared around the time the positivity was hypothesised.

Topographic maps of difference waveforms (switch – repeat), referred to as topographic dissimilarity maps, were created for the mixed block of each paradigm across the 500-600ms interval, and for periods of significance at Pz, to examine the scalp distributions of switch effects. To analyse these, the mean amplitude at each electrode site during the period of Pz significance was calculated, and paired-samples *t*-tests were used to determine sites at which there was a significant difference. The method of analysing periods in which waveform differences showed either consecutive significance or the greatest effects, to examine the scalp distributions of this effect, is often used in the task switching literature (e.g. Dumontheil et al., 2010; Swainson et al., 2006), and Swainson et al. (2006) similarly conducted *t*-tests at each electrode site to determine sites of significant difference. Due to an inflated risk of Type I errors, effect sizes were considered crucial for interpretations drawn from these maps. Effect sizes were also critical given the limited sample size in this study, as they are less affected by lack of power than *p*-values. Only electrodes which were both significant at α=.05 *and* had an effect size above negligible ($g \geq 0.20$) were considered to show a meaningful difference.

Results

Behavioural Data

Table 3 shows response times for repeat and switch/change trials in pure and mixed blocks of the traditional and sincerity switching paradigms, and Table 4 presents the ANOVA statistics. Analysis of response times revealed a significant Paradigm × Block × Trial Type interaction. This interaction was broken down by Paradigm, revealing significant Block × Trial Type interactions in both the traditional, and sincerity switching paradigms, such that the difference between trial types was greater for mixed in comparison to pure block trials. To test the hypotheses, tests of simple main effects were conducted separately for each block type. Change and repeat trial response times did not differ significantly during the pure block in either the traditional or the sincerity paradigm. However, during mixed blocks, response times to switch trials were significantly longer than response times to repeat trials in both traditional and sincerity paradigms.

Table 3

Response Time (ms) and Accuracy (%) Estimates for Repeat and Switch Trials in Pure and Mixed Blocks of Traditional and Sincerity Paradigms

	Response Time			Accuracy		
Condition	*M*	*SD*	95% CI of *M*	*M*	*SD*	95% CI of *M*
Sincerity - Pure Block						
Repeat	665.9	150.2	[585.9, 746.0]	97.5	3.8	[95.5, 99.5]
Change	675.2	178.6	[580.1, 770.4]	97.1	3.5	[95.2, 99.0]
Sincerity - Mixed Block						
Repeat	1,117.2	287.6	[964.0, 1,270.5]	93.2	6.6	[89.7, 96.7]
Switch	1,278.4	331.6	[1,101.7, 1,455.1]	91.5	6.7	[87.9, 95.4]
Traditional – Pure Block						
Repeat	638.5	128.4	[570.1, 707.0]	97.2	2.6	[95.8, 98.6]
Change	646.8	135.0	[574.9, 718.7]	97.7	1.8	[96.8, 98.7]
Traditional - Mixed Block						
Repeat	1,218.7	312.2	[1,052.4, 1,385.1]	93.8	5.7	[90.7, 96.8]
Switch	1,314.7	360.2	[1,122.8, 1,506.6]	94.2	4.4	[91.9, 96.6]

Table 4

Repeated Measures ANOVA Statistics for Response Times (ms)

Comparison	*F*	*p*	*Effect size*
Paradigm × Block × Trial Type	7.98	.013*	$\eta^2_p = .35$
Within Sincerity Paradigm			
Block × Trial Type	24.27	<.001*	$\eta^2_p = .62$
Trial Type within Pure Block	0.69	.418	$g = 0.06$
Trial Type within Mixed Block	35.59	< .001**	$g = 0.51$
Within Traditional Paradigm			
Block × Trial Type	10.77	.005*	$\eta^2_p = .42$
Trial Type within Pure Block	1.92	.187	$g = 0.06$
Trial Type within Mixed Block	15.06	.001**	$g = 0.28$

Notes. Degrees of freedom are 1, 15 for all.
* $p<.05$ for omnibus comparisons. ** $p<.0125$ for tests of simple effects (Bonferroni corrected).

Table 5

Repeated Measures ANOVA Statistics for Accuracy (% of correct trials)

Comparison	*F*	*p*	*Effect size*
Paradigm × Block × Trial Type	0.42	.526	$\eta^2_p = .03$
Paradigm × Block	0.69	.418	$\eta^2_p = .04$
Paradigm × Trial Type	1.62	.222	$\eta^2_p = .10$
Block × Trial Type	0.66	.431	$\eta^2_p = .04$
Paradigm	0.85	.372	$g = 0.25$
Block	21.57	<.001*	$g = 1.22$
Trial Type	0.59	.455	$g = 0.09$

Notes. Degrees of freedom are 1, 15 for all.
* indicates $p<.05$.

An accuracy analysis was conducted to examine whether response time costs were due to a response time–accuracy trade-off. Table 3 shows the mean percentage of correct trials for repeat and switch/change trials in pure and mixed blocks of the each paradigm, and Table 5 presents the results of the ANOVA. The only significant effect was a main effect of Block, such that accuracy was significantly lower in mixed blocks (*M*=93.4, *SD*=4.2, 95% CI[90.9, 95.4]), than pure blocks (*M*=97.4, *SD*=2.4, 95% CI[96.1, 98.6]).

ERP Waveforms at Pz

Figures 3 and 4 show grand averaged waveforms at midline parietal electrode site Pz for pure and mixed blocks respectively. In these waveforms, components P1, N1 and P3 can be seen, signifying the processing of visual stimuli. In the mixed block, switch and repeat waveforms show a sustained divergence beginning about 400ms post-target, whereby switch waveforms appear more negative than repeat waveforms. This difference continues until about 600ms for traditional paradigm waveforms, and about 900ms for sincerity paradigm waveforms. In both paradigms, differences between switch and repeat waveforms appear greatest between 500 and 600ms. In contrast, waveforms in the pure block do not appear to diverge in the interval between 500 and 600ms. Figure 5 shows difference waveforms (switch – repeat) for the mixed blocks of both paradigms. The negativity appears greatest between about 500 and 550ms post-target in the traditional, and at about 550ms in the sincerity paradigm. There does not appear to be a sustained positivity in the switch – repeat waveforms.

Pz amplitude estimates for each 5ms mini-epoch analysed are reported in Tables 6 and 7, and the consecutive *t*-test analysis is reported in Tables 8 and 9 for sincerity and traditional paradigms respectively. Runs of significance occurred from

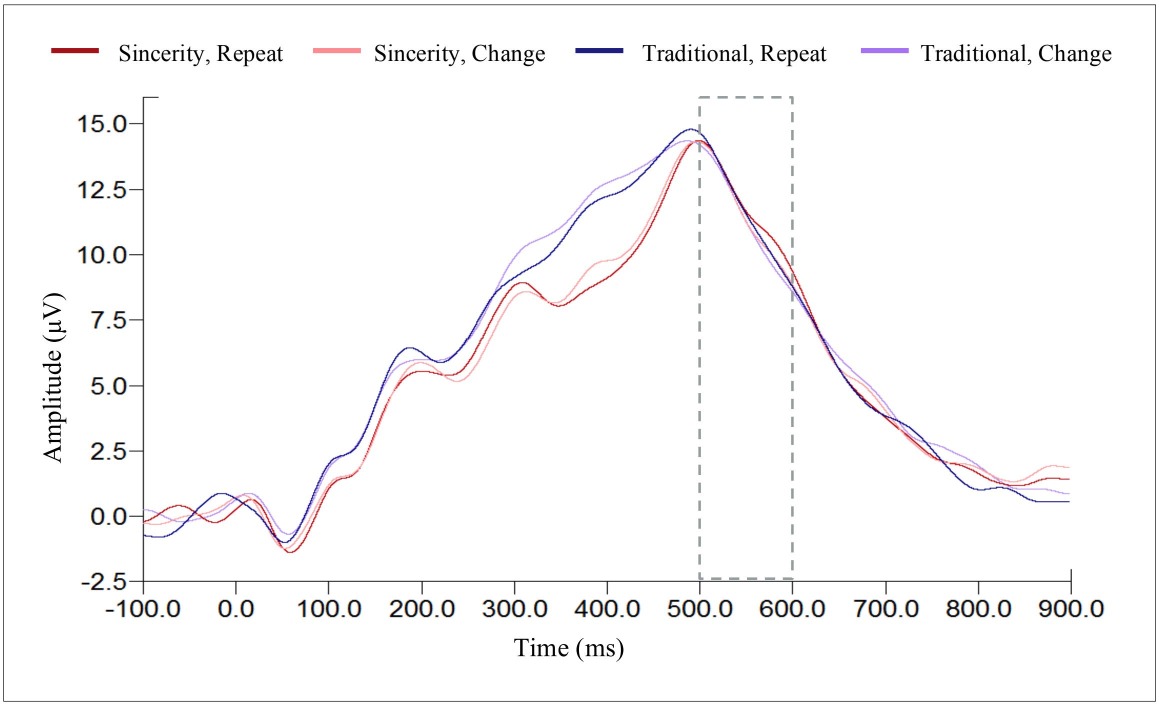

Figure 3. Grand Averaged Waveforms at Pz for Repeat and Change Trials in Pure Blocks of the Traditional and Sincerity Switching Paradigms.

Note. Period analysed in the mixed block is outlined here in grey for comparison.

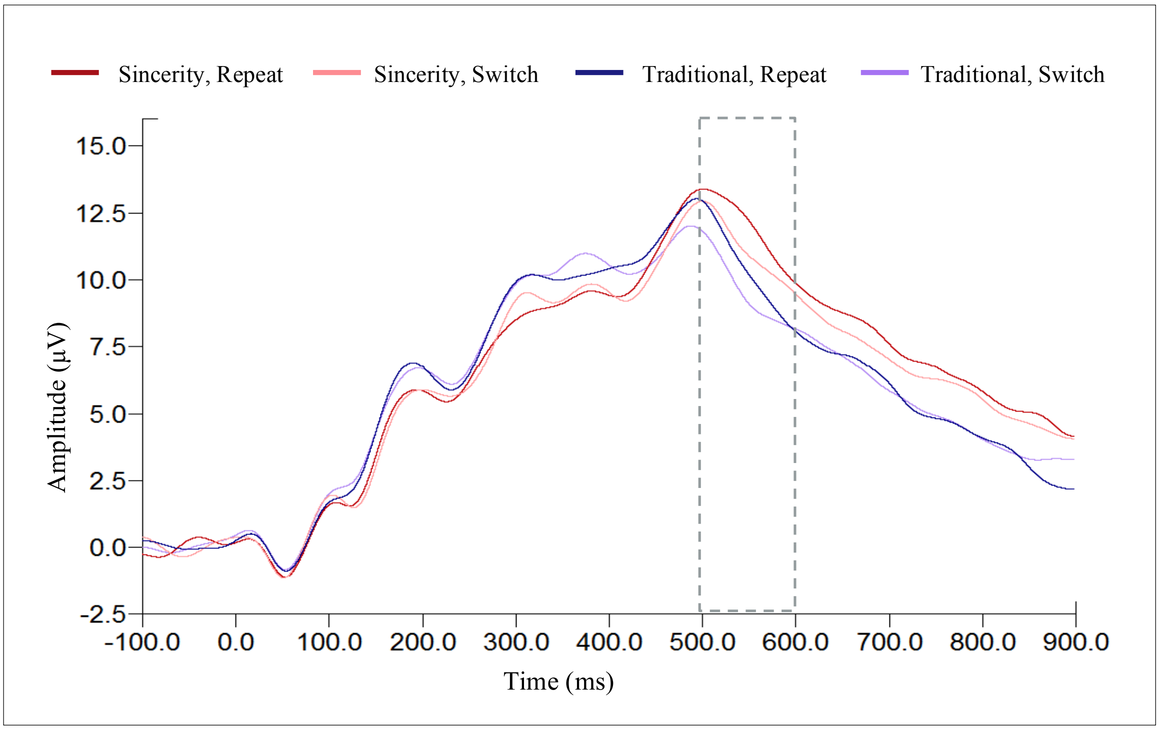

Figure 4. Grand Averaged Waveforms at Pz for Repeat and Switch Trials in Mixed Blocks of the Traditional and Sincerity Switching Paradigms.

Note. 500 to 600 millisecond period analysed is outlined in grey.

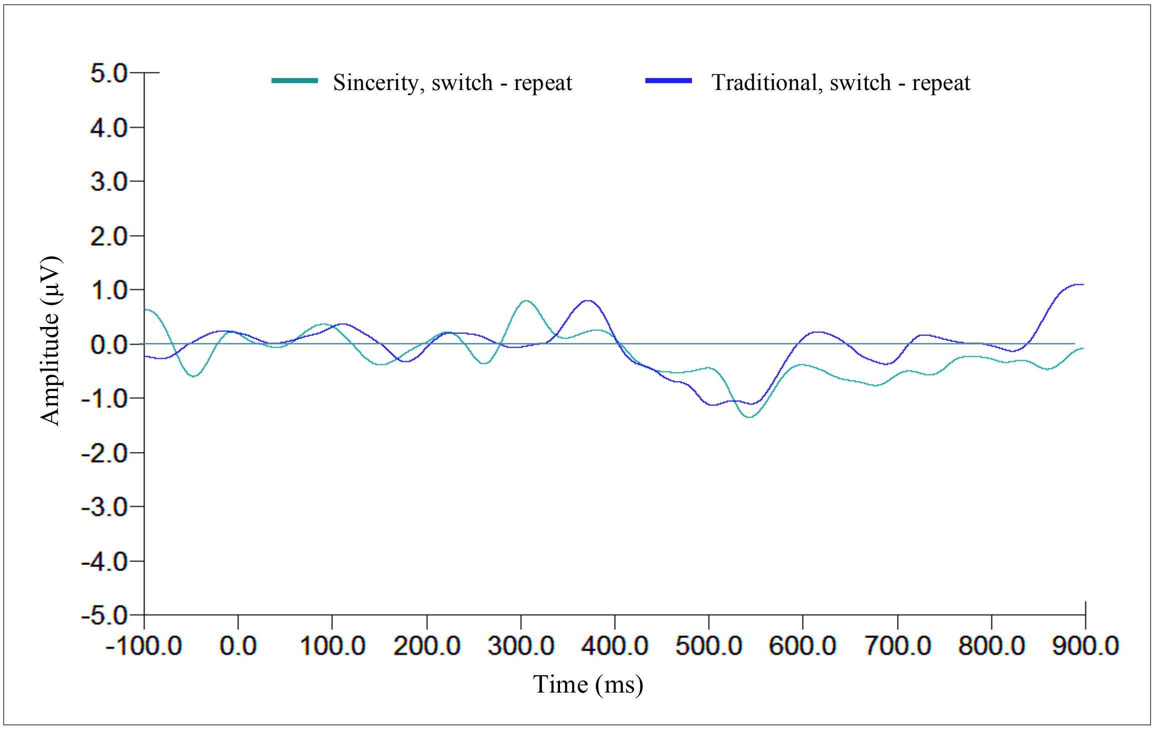

Figure 5. Grand Averaged Difference Waveforms at Pz (Switch – Repeat) for Mixed Blocks of the Traditional and Sincerity Switching Paradigms.

Note. Reference line added at 0 microvolts.

535–545ms in the sincerity paradigm, and from 500–515ms in the traditional paradigm, although effect sizes were greater than negligible from 525–560ms in the sincerity, and 500–565ms in the traditional paradigm.

Scalp Topography of Negativities

Figures 6 and 7 present topographic dissimilarity maps (switch – repeat) averaged over each 5ms mini-epoch in the 500-600ms interval, for sincerity and traditional paradigms respectively. Negativities appear in both paradigms at parietal and central sites, and at parietal sites they appear slightly left lateralised. At central sites, the negativity appears right lateralised in the sincerity paradigm, and left lateralised in the traditional paradigm, however, the following analyses do not necessarily permit comparison of the topographic distributions of negativities

Table 6

Amplitude Estimates at Pz during each Mini Epoch for Switch and Repeat Trials in the Mixed Block of the Sincerity Switching Paradigm

Mini Epoch	Switch Waveform			Repeat Waveform		
(ms)	*M*	*SD*	95% CI of *M*	*M*	*SD*	95% CI of *M*
500-505	13.2	5.0	[10.6, 15.9]	13.6	4.9	[11.0, 16.2]
505-510	13.2	4.8	[10.6, 15.7]	13.5	4.9	[10.9, 16.1]
510-515	13.0	4.6	[10.5, 15.5]	13.4	4.9	[10.8, 16.0]
515-520	12.7	4.4	[10.4, 15.1]	13.2	4.9	[10.7, 15.8]
520-525	12.4	4.3	[10.1, 14.7]	13.1	4.9	[10.5, 15.7]
525-530	12.0	4.3	[9.7, 14.2]	13.0	4.9	[10.4, 15.6]
530-535	11.5	4.4	[9.2, 13.8]	12.9	4.9	[10.3, 15.5]
535-540	11.2	4.5	[8.8, 13.6]	12.8	5.0	[10.1, 15.4]
540-545	10.9	4.8	[8.4, 13.5]	12.6	5.1	[9.9, 15.3]
545-550	10.8	5.1	[8.1, 13.5]	12.4	5.2	[9.7, 15.2]
550-555	10.7	5.5	[7.8, 13.6]	12.2	5.3	[9.4, 15.0]
555-560	10.7	5.7	[7.6, 13.7]	11.9	5.4	[9.0, 14.8]
560-565	10.6	5.8	[7.5, 13.6]	11.6	5.5	[8.7, 14.6]
565-570	10.4	5.7	[7.4, 13.5]	11.3	5.6	[8.3, 14.3]
570-575	10.3	5.7	[7.2, 13.3]	11.0	5.7	[8.0, 14.1]
575-580	10.1	5.6	[7.1, 13.1]	10.7	5.8	[7.7, 13.8]
580-585	10.0	5.5	[7.0, 12.9]	10.4	5.8	[7.4, 13.5]
585-590	9.9	5.4	[7.0, 12.7]	10.2	5.8	[7.1, 13.3]
590-595	9.8	5.2	[7.0, 12.5]	10.0	5.7	[7.0, 13.1]
595-600	9.6	4.9	[7.0, 12.2]	9.9	5.7	[6.8, 12.9]

Note. Estimates are in µV.

Table 7

Amplitude Estimates at Pz during each Mini Epoch for Switch and Repeat Trials in the Mixed Block of the Traditional Task Switching Paradigm

Mini Epoch	Switch Waveform			Repeat Waveform		
(ms)	*M*	*SD*	95% CI of *M*	*M*	*SD*	95% CI of *M*
500-505	11.9	4.1	[9.7, 14.1]	13.3	4.5	[10.9, 15.7]
505-510	11.7	4.1	[9.5, 13.9]	13.0	4.5	[10.6, 15.5]
510-515	11.4	4.1	[9.2, 13.6]	12.6	4.6	[10.2, 15.1]
515-520	11.1	4.1	[8.9, 13.3]	12.2	4.7	[9.7, 14.6]
520-525	10.8	4.1	[8.6, 12.9]	11.7	4.7	[9.2, 14.2]
525-530	10.4	4.2	[8.2, 12.6]	11.3	4.8	[8.8, 13.9]
530-535	10.0	4.2	[7.8, 12.2]	11.0	4.9	[8.4, 13.6]
535-540	9.7	4.2	[7.4, 11.9]	10.7	5.0	[8.0, 13.4]
540-545	9.4	4.2	[7.1, 11.6]	10.5	5.1	[7.8, 13.2]
545-550	9.1	4.1	[6.9, 11.3]	10.2	5.1	[7.5, 13.0]
550-555	8.8	4.1	[6.6, 11.0]	10.0	5.2	[7.3, 12.8]
555-560	8.6	4.1	[6.5, 10.8]	9.8	5.2	[7.1, 12.6]
560-565	8.6	4.1	[6.4, 10.7]	9.6	5.2	[6.8, 12.4]
565-570	8.5	4.1	[6.4, 10.7]	9.4	5.3	[6.6, 12.2]
570-575	8.5	4.1	[6.3, 10.7]	9.1	5.2	[6.3, 11.9]
575-580	8.5	4.2	[6.3, 10.7]	8.9	5.2	[6.1, 11.7]
580-585	8.5	4.1	[6.3, 10.7]	8.7	5.1	[6.0, 11.4]
585-590	8.3	4.1	[6.2, 10.5]	8.5	5.0	[5.8, 11.2]
590-595	8.2	3.9	[6.1, 10.3]	8.3	5.0	[5.6, 10.9]
595-600	8.2	3.8	[6.1, 10.2]	8.1	4.9	[5.4, 10.7]

Note. Estimates are in µV.

Table 8

Consecutive t-tests Conducted between Switch and Repeat Waveforms at Pz in Mixed Blocks of the Sincerity Switching Paradigm

Mini Epoch (ms)	*t*	*p*	Hedges' *g*	95% CI of Difference
500 to 505	0.61	.549	.08	[-0.97, 1.75]
505 to 510	0.58	.573	.08	[-1.02, 1.78]
510 to 515	0.62	.545	.08	[-1.00, 1.82]
515 to 520	0.79	.445	.11	[-0.88, 1.91]
520 to 525	1.12	.280	.15	[-0.65, 2.09]
525 to 530	1.60	.132	.22	[-0.34, 2.38]
530 to 535	2.06	.058	.28	[-0.05, 2.75]
535 to 540	2.31	.035*	.33	[0.13, 3.10]
540 to 545	2.27	.038*	.34	[0.11, 3.24]
545 to 550	1.99	.065	.31	[-0.12, 3.40]
550 to 555	1.63	.124	.26	[-0.45, 3.34]
555 to 560	1.32	.206	.21	[-0.74, 3.18]
560 to 565	1.13	.277	.18	[-0.92, 3.00]
565 to 570	1.01	.331	.16	[-1.02, 2.83]
570 to 575	0.87	.399	.13	[-1.13, 2.68]
575 to 580	0.68	.510	.10	[-1.31, 2.53]
580 to 585	0.48	.639	.08	[-1.52, 2.39]
585 to 590	0.35	.735	.06	[-1.64, 2.28]
590 to 595	0.29	.775	.05	[-1.66, 2.18]
595 to 600	0.31	.759	.05	[-1.57, 2.10]

Notes. Degrees of freedom = 15 for all comparisons. Effect size signs are reported contrary to hypothesis direction for ease of interpretation.
* = tests considered significant using the criteria of consecutive significance.

Table 9

Consecutive t-tests Conducted between Switch and Repeat Waveforms at Pz in Mixed Blocks of the Traditional Switching Paradigm

Mini Epoch (ms)	*t*	*p*	Hedges' *g*	95% CI of Difference
500 to 505	2.82	.013*	.32	[0.34, 2.47]
505 to 510	2.79	.014*	.31	[0.32, 2.41]
510 to 515	2.46	.027*	.27	[0.16, 2.26]
515 to 520	2.09	.054	.24	[-0.02, 2.14]
520 to 525	1.87	.081	.22	[-0.14, 2.09]
525 to 530	1.83	.087	.21	[-0.16, 2.09]
530 to 535	1.89	.079	.21	[-0.13, 2.11]
535 to 540	1.95	.071	.22	[-0.10, 2.17]
540 to 545	1.98	.066	.23	[-0.08, 2.28]
545 to 550	2.01	.063	.25	[-0.07, 2.43]
550 to 555	2.01	.063	.25	[-0.08, 2.55]
555 to 560	1.90	.077	.25	[-0.15, 2.58]
560 to 565	1.65	.120	.22	[-0.31, 2.44]
565 to 570	1.29	.218	.17	[-0.54, 2.20]
570 to 575	0.91	.378	.12	[-0.78, 1.93]
575 to 580	0.61	.551	.08	[-0.95, 1.70]
580 to 585	0.40	.692	.05	[-1.04, 1.52]
585 to 590	0.24	.813	.03	[-1.09, 1.37]
590 to 595	0.05	.959	.01	[-1.17, 1.23]
595 to 600	-0.19	.851	-.02	[-1.32, 1.10]

Notes. Degrees of freedom = 15 for all comparisons. Effect size signs are reported contrary to hypothesis direction for ease of interpretation.
* = tests considered significant using the criteria of consecutive significance

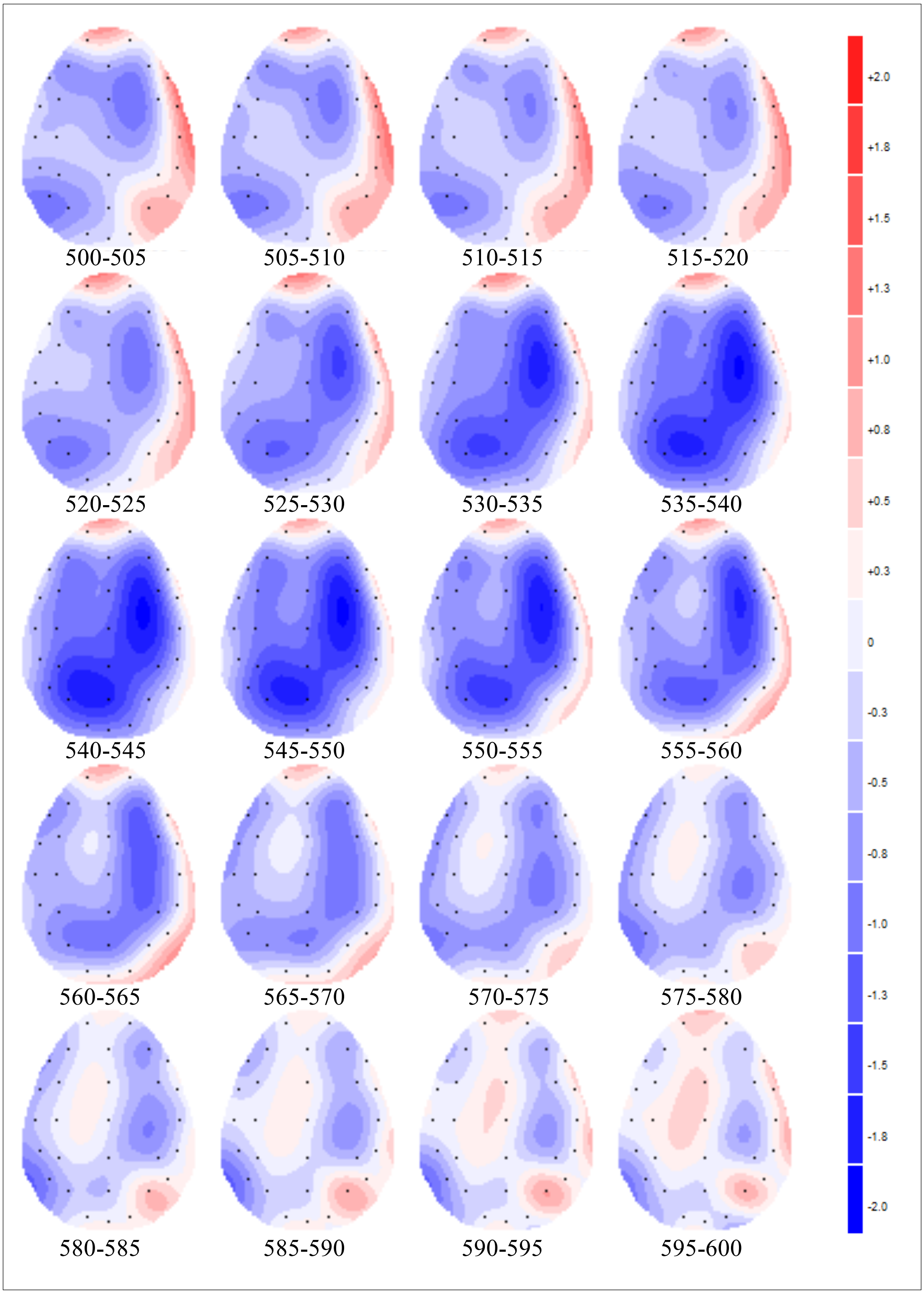

Figure 6. Topographic Dissimilarity Maps for the Sincerity Switching Paradigm (Mixed Block: Switch – Repeat) 500 to 600 milliseconds Post-Target.

Note. Averaged over 5 millisecond mini-epochs.

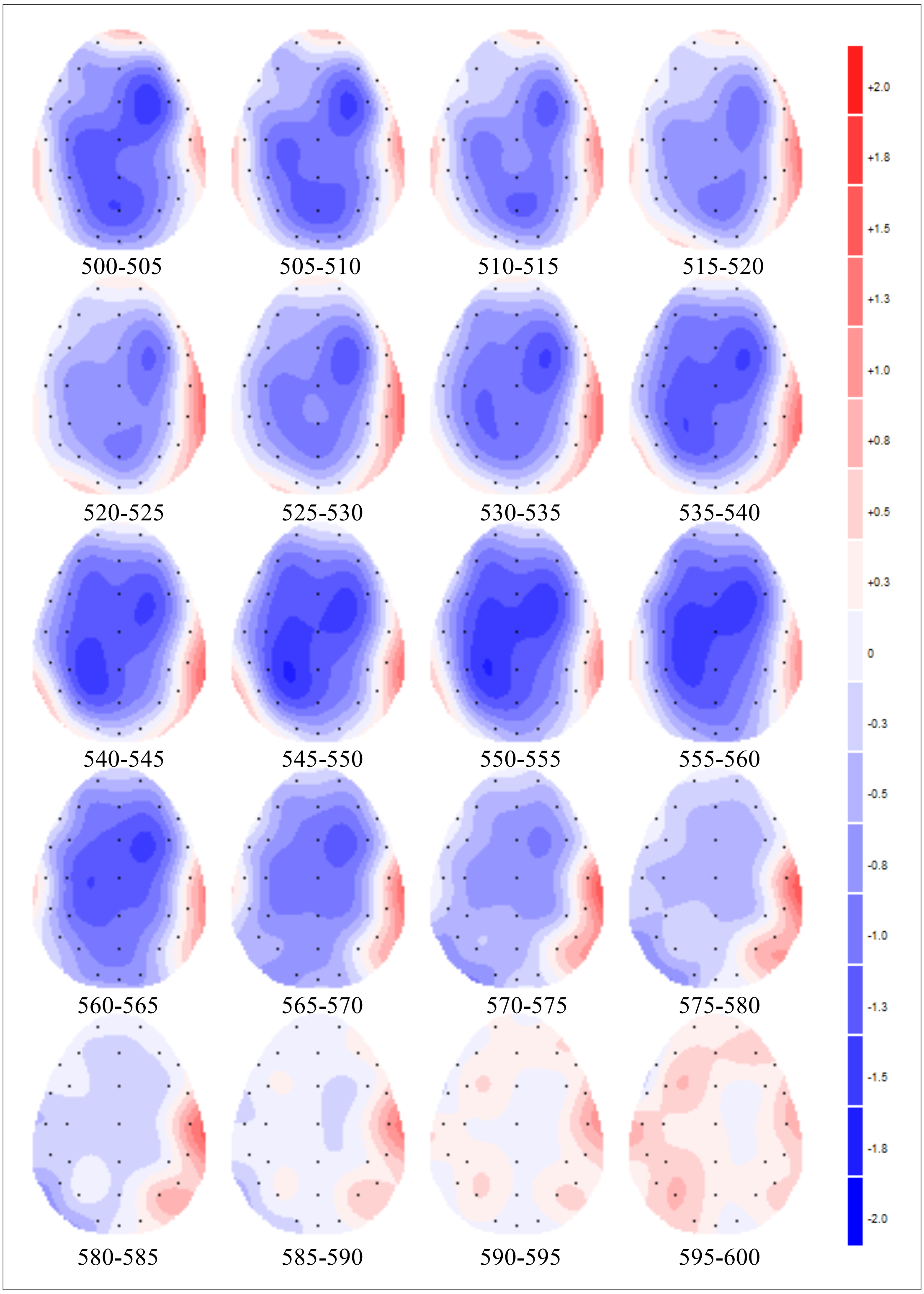

Figure 7. Topographic Dissimilarity Maps for the Traditional Switching Paradigm (Mixed Block: Switch – Repeat) 500 to 600 milliseconds Post-Target.

Note. Averaged over 5 millisecond mini-epochs.

Table 10

T-test statistics of the Switch – Repeat Difference at Each Electrode Site at 535 – 545ms in the Sincerity Paradigm

Electrode	*t*	*df*	*p*	Hedges' *g*	95% CI of Difference
O2	1.68	14	.116	0.18	[-0.24, 1.94]
O1	1.94	15	.072	0.25◆	[-0.11, 2.20]
Oz	1.74	15	.102	0.18	[-0.19, 1.95]
Pz	2.30	15	.037*	0.34◆	[0.12, 3.21]
P4	1.12	10	.289	0.19	[-0.74, 2.24]
CP4	2.71	15	.016*	0.37◆	[0.24, 2.02]
P8	1.10	15	.288	0.16	[-0.39, 1.21]
TP8	1.49	14	.158	0.22◆	[-0.22, 1.25]
T8	1.37	14	.192	0.18	[-0.29, 1.33]
P7	2.29	15	.037*	0.51◆	[0.08, 2.27]
P3	2.23	15	.042*	0.43◆	[0.07, 3.02]
CP3	1.85	15	.084	0.34◆	[-0.20, 2.83]
CPz	1.99	15	.065	0.32◆	[-0.10, 3.03]
Cz	1.65	15	.120	0.24◆	[-0.37, 2.88]
FC4	2.22	14	.044*	0.31◆	[0.04, 2.61]
FT8	0.34	15	.736	0.04	[-0.62, 0.86]
TP7	1.69	15	.111	0.30◆	[-0.19, 1.63]
C3	1.34	15	.201	0.24◆	[-0.57, 2.49]
FCz	1.31	15	.210	0.17	[-0.64, 2.69]
Fz	0.83	15	.421	0.12	[-1.08, 2.45]
F4	1.59	15	.133	0.20◆	[-0.37, 2.51]
F8	0.53	15	.601	0.06	[-0.64, 1.08]
T7	0.96	15	.350	0.15	[-0.69, 1.82]
FT7	0.77	15	.452	0.11	[-0.79, 1.69]
FC3	1.11	14	.287	0.19	[-0.84, 2.64]
F3	1.05	15	.312	0.17	[-0.88, 2.57]
FP2	0.11	15	.913	0.02	[-1.31, 1.45]
F7	0.58	15	.574	0.04	[-1.00, 1.75]
FP1	-0.36	15	.721	-0.03	[-1.94, 1.37]

Note. 535-545ms latency is examined as Pz produced a significant difference during this time period in the sincerity switching paradigm.

* $p < .05$, ◆ $g \geq 0.2$

Table 11

T-test statistics of the Switch – Repeat Difference at Each Electrode Site at 500 – 515ms in the Traditional Paradigm

Electrode	*t*	*df*	*p*	Hedges' *g*	95% CI of Difference
O2	1.47	14	.164	0.16	[-0.32, 1.69]
O1	1.39	14	.186	0.14	[-0.29, 1.37]
Oz	1.56	15	.140	0.13	[-0.22, 1.41]
Pz	2.43	15	.028*	0.26◆	[0.15, 2.25]
P4	1.03	10	.329	0.14	[-0.78, 2.10]
CP4	1.61	15	.127	0.14	[-0.19, 1.40]
P8	0.70	15	.496	0.08	[-0.51, 1.00]
TP8	-0.29	14	.769	-0.05	[-0.96, 0.73]
T8	-0.77	14	.456	-0.12	[-1.33, 0.63]
P7	0.95	14	.358	0.13	[-0.34, 0.89]
P3	1.96	15	.069	0.21◆	[-0.06, 1.36]
CP3	2.19	15	.045*	0.20◆	[0.02, 1.48]
CPz	2.29	15	.037*	0.21◆	[0.07, 1.93]
Cz	2.62	15	.019*	0.17	[0.19, 1.84]
FC4	2.04	15	.059	0.16	[-0.04, 1.93]
FT8	0.02	14	.987	<0.01	[-1.01, 1.02]
TP7	0.78	15	.446	0.10	[-0.36, 0.78]
C3	2.27	14	.040*	0.19	[0.05, 1.63]
FCz	2.11	15	.052	0.14	[-0.01, 1.81]
Fz	1.29	15	.218	0.09	[-0.39, 1.56]
F4	1.40	15	.181	0.11	[-0.32, 1.57]
F8	-0.08	14	.937	-0.01	[-1.10, 1.02]
T7	0.26	15	.800	0.02	[-0.50, 0.64]
FT7	1.12	15	.282	0.11	[-0.34, 1.08]
FC3	1.18	14	.257	0.10	[-0.39, 1.34]
F3	1.08	15	.296	0.10	[-0.51, 1.58]
FP2	-0.21	15	.838	-0.02	[-1.24, 1.02]
F7	0.43	14	.673	0.05	[-0.74, 1.11]
FP1	0.48	15	.639	0.04	[-0.75, 1.18]

Note. 500-515ms latency is examined as Pz produced a significant difference during this time period in the traditional switching paradigm.
* $p < .05$, ◆ $g \geq 0.2$

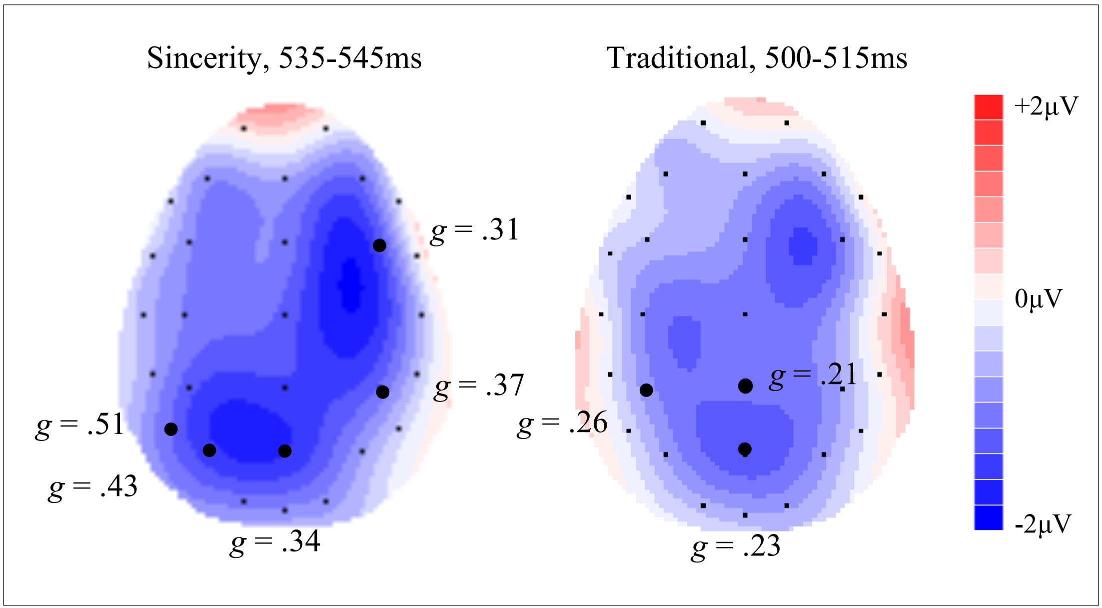

Figure 8. Topographic Dissimilarity Maps (Mixed Block: Switch – Repeat) for Each Paradigm Averaged over Periods of Significant Difference at Pz.

Note. Electrodes for which there was a significant difference in this period ($p<.05$), in combination with an above negligible effect are presented in bold.

between the two paradigms. Differences between the two (switch – repeat) negativities were not compared statistically because the topographic analyses were conducted within different timeframes, so are not necessarily comparable. Also, the difference between traditional and sincerity paradigm negativities is in the range of 1μV. This study may lack sufficient power to detect such subtle differences. However, these maps are useful in representing the topography of negativities within each paradigm.

Figure 8 presents topographic dissimilarity maps (switch – repeat) for mixed blocks of each paradigm, over periods of significant amplitude difference at Pz. To examine the scalp topographies of the negativities, *t*-tests were used to compare mean amplitudes between switch and repeat conditions at each electrode site, at latencies for which there was a significant difference at Pz. Electrode C4 was excluded from analyses due to equipment malfunction. The electrodes that produced a meaningful difference (p<.05 and $g \geq 0.20$) were Pz, CP4, P7, P3 and FC4 in the sincerity paradigm, and Pz, CP3 and CPz in the traditional paradigm (indicated in Figure 8). Results of tests at all electrode sites are shown in Table 10 and Table 11 for sincerity and traditional paradigms respectively

Discussion

The present study investigated whether markers of task switching could be found when individuals switched between lying and telling the truth. These markers included response time switch costs, and ERP differences between switch and repeat trials in mixed blocks observed at Pz around 400-600ms post-target. As hypothesised, significant switch costs were found in both sincerity switching and traditional task switching paradigms. Contrary to hypotheses, a switch positivity was not observed in either paradigm, however evidence of switch-related negativities were found at similar latencies in each paradigm within a 500-600ms post-target interval.

Behavioural Switch Costs

As hypothesised, switch costs were observed in both the traditional and sincerity switching paradigms, as participants took significantly longer to respond on switch trials than on repeat trials during mixed blocks. This difference did not appear to be caused by the target colour changes occurring on switch trials, as costs in mixed blocks were significantly greater than in pure blocks, such that no significant response time difference was observed in the pure blocks between repeat trials and trials involving a colour change (but no task switch). An accuracy analysis revealed that response time costs on switch trials were not a result of a response time-accuracy trade-off, as accuracy rates showed no significant differences between mixed block switch and repeat trials. The behavioural switch costs found in this study support the switch cost found in another study in which participants switched between lying and telling the truth (Debey et al., 2015), and suggest that task switching processes may be engaged when participants switch response sincerity type.

The switch cost observed in the sincerity paradigm produced a moderate effect size, whereas the effect size observed in the traditional paradigm was small. A possible reason for this is that targets used in the traditional paradigm could be congruent (both tasks are associated with the same response key) or incongruent (each task is associated with different response keys). Due to the nature of the lie-truth tasks however, every target in the sincerity paradigm was incongruent. Incongruent targets often produce greater switch costs than congruent targets (Kieffaber, Kruschke, Cho, Walker, & Hetrick, 2013), possibly explaining the greater switch effect observed in the sincerity paradigm.

Switch Differences in ERPs

In the present study, there was evidence for a significant switch-related negativity at the parietal midline electrode site (Pz) within the same 500-600ms interval post-target (although at slightly different latencies) in both the traditional and the sincerity switching paradigms. The presence of this negativity in both paradigms, in addition to an apparent lack of difference between waveforms in the pure block, suggests that similar task switching processes may have been used to complete switch trials in both paradigms.

These negativities were less sustained than those observed in previous literature. For example, Karayanidis (2006) found a centroparietal switch negativity emerging 300ms post-target, and extending until about 500ms post-target, and in a cued paradigm, Rushworth et al. (2002) found a negativity between 200 and 360ms post-target. However, the present study was somewhat underpowered, which may have reduced the significance of some periods of this negativity. In fact, there were comparisons adjacent to each run of significance that were approaching significance, and effect sizes were greater than negligible from 525-560 ms in the sincerity paradigm, and from 500-565 ms in the traditional paradigm. As comparatively short negativities emerged in both traditional and sincerity switching paradigms, it is also possible that an aspect of paradigm design caused this shorter duration. Given that the current study used quite a long response-stimulus interval (i.e. 2,000–3,000 ms, compared to 150, 300, 600 and 1,200ms used by Karayanidis et al., 2006; and 1,000ms used by Rushworth et al., 2002), it is possible that there was increased time for task set dissipation to occur, meaning less interference to resolve during the current paradigms, possibly causing the negativity to be less sustained than in the studies cited above. When designing the paradigms, as the cue-target interval was effectively zero, it was thought this would result in the greatest switch costs and ERP differences, as switching is more difficult when shorter preparation intervals are used (Jamadar et al., 2015). However, although there was no preparation time, the long response-target interval may have caused activations from the previous task to dissipate sufficiently as to result in less target-driven interference, and a shortened switch negativity in comparison to other research.

Contrary to hypotheses, a sustained switch positivity was not observed at electrode site Pz, in either the traditional or sincerity paradigm. Given that no positivity was observed in the traditional paradigm, the absence of positivity in the sincerity paradigm is likely a result of paradigm design parameters, rather than an absence of the necessity to task switch. But why would no positivity occur in either paradigm? It is possible, as the switch positivity usually occurs after a cue and before the target, that it reflects *only* anticipatory task set reconfiguration, a process that does not occur when there is no preparation interval in which to engage in anticipatory processes. The switch positivity resolves after target presentation in paradigms with short cue-target intervals, or short response-target intervals when trials are completed according to a memorised sequence (Jamadar et al., 2015; Karayanidis et al., 2006). It is possible that, in these cases the positivity (or processes leading up to it) did begin in the interval before the target, but target onset was so rapid that the positivity still needed to resolve before the negativity could occur (or appear in the waveform). In the response-locked Pz waveforms reported by Karayanidis et al. (2006), the positivity seems to begin slightly before target onset, but only becomes significant exactly at or slightly after target onset (in response-stimulus intervals of 150ms and 300ms respectively). As their paradigm had an (albeit very short) anticipatory period, it is possible this caused anticipatory reconfiguration to begin, and the switch positivity to occur. In contrast, the current paradigm had no anticipatory period, preventing the occurrence of anticipatory reconfiguration, possibly causing the absence of a switch positivity.

However, it is unclear why Swainson et al. (2006) found a switch positivity after target onset in a paradigm with no anticipatory period, in which target colour signalled task rules. However, their paradigm was somewhat dissimilar to those used in standard task switching paradigms. For both tasks, participants classified the direction of an arrow stimulus as left or right, meaning target-response mappings did not change between tasks. The only difference was that one task involved responding immediately and the other involved delaying a response until stimulus offset (Swainson et al., 2006). It is possible that the positivity observed in this study reflected a dissimilar process to that of a switch positivity, such as processes used to alter response timing. Also in contrast to the current study, Swainson et al. (2006) did not observe a negativity after target presentation. It is possible that their post-target positivity obscured a switch negativity (as it occurred 524–808ms post-target). However, as the switch negativity is thought to reflect resolution of target-driven interference, it is also possible that this interference did not occur because the same task set was activated for each task, as the same stimulus afforded the same response on each trial.

Scalp Topographies

Within time periods where significant negativities were observed at Pz, the scalp distribution of these negativities was examined by testing for differences at all electrode sites during these intervals. A number of other centroparietal and parietal electrodes returned significant negativities in combination with greater-than-negligible effect sizes in the sincerity and traditional paradigms. These centro-parietal topographies are comparable to the topography of a switch negativity (Jamadar et al., 2015; Karayanidis & Jamadar, 2014), adding to the evidence suggesting that, in the sincerity paradigm, the negativity may be caused by task switching processes that occurred when participants switched between responding truthfully and deceptively.

Methodological Limitations

In addition to the long response-target interval, another limitation of the current study concerns the lack of power. The power calculation indicated 25 participants would be required to detect a moderate effect, however the final sample consisted of 16. As a result, periods of meaningful difference in ERPs may have been nonsignificant. Also due to the limited sample (and high number of comparisons), common ways of controlling for Type I errors were considered too conservative for the topographic dissimilarity analysis. Therefore, the current approach of requiring statistical significance in combination with non-negligible effect sizes was considered an appropriate approach to balance Type I and Type II errors.

Another limitation concerns a lack of ecological validity. Lying about an image having been on a memorised list is not necessarily comparable to lying about having committed a crime. Using memorisation ensured that participants were lying about knowledge they had stored in memory, which may be similar to lying about a crime because having committed the crime is also stored in memory (although a distinction could be made between semantic and episodic memory). However, lying in a high stakes situation may involve many other processes (e.g. motivational and emotional) that could potentially affect task switching processes. Research in this area would be vital before markers of task switching could be used to detect deception in a forensic context.

Another limitation is the possibility that participants used response switching, rather than sincerity switching, to complete the sincerity paradigm. This would involve participants activating the truthful response, and then merely switching response key mappings to respond on lie trials. Task instructions are crucial to creating mental task sets (Schneider & Logan, 2014). For example, Dreisbach et al. (2007) found that when participants were instructed to memorise and respond using eight target-response mappings, no switch costs were observed. However, in the same paradigm, when participants were instructed to perform two different tasks on the targets (even after they had memorised the simple and valid response mappings), switch costs were observed, suggesting that participants began using the task instructions. It is possible that, while response switching could have been used to complete the sincerity paradigm, instructions indicating to tell the truth or to lie created ‘truth’ and ‘lie’ mental task sets that participants used to complete the study. In fact, reviewing the qualitative task questionnaires revealed that three participants mentioned they learned to associate the colour of the target with ‘lie’ or ‘truth’, and nothing equating to response switching was mentioned.

A related question concerns whether a clear distinction can really be made between response switching and switching between lying and telling the truth to yes-no questions. It is possible that guilty suspects may use this sort of response switching to respond deceptively in forensic contexts. Whether or not a distinction can be made between response and sincerity switching, either process would need to be engaged for guilty suspects, but not for innocents, so markers of either type of switching could indicate guilt.

Implications and Future Research

This study has implications for potential future directions in deception detection, as well as for theories of task switching. The results support the idea that switch positivities may index only anticipatory task set reconfiguration, a process that does not occur when there is no preparation interval. As the switch positivity did not occur in either paradigm (but switch costs were observed in both suggesting task switching was necessary) it appears that processes indexed by the switch positivity are not required to switch tasks. Rather, these anticipatory processes may merely facilitate task switching when preparation intervals are provided.

The current study adds to the variety of paradigms and task types that have been found to produce switch-related ERP differences. Relevant to the hypotheses, the results also suggest that task switching processes may be used when individuals switch between lying and telling the truth, and that markers of task switching may have potential for detecting deception. However, extensive further research would be needed before this technique could be used in a forensic setting. Research would be needed to address a potential response switching confound, and the ecological validity and power limitations of the current study, as well as to replicate the current findings in similar and diverse samples, and to expand on the area of task switching in a deception context in general. Future research would also be needed to outline paradigm parameters, constraints, limitations and likely success rates of using a sincerity switching lie detector before this method could be used to assist a criminal investigation.

How could responding to yes-no questions about images be developed into a lie detector that could be used in forensic settings? It would be difficult to present crime and non-crime related questions in sentence format to suspects, as ERP measures are time-locked to stimulus presentation, and using sentences causes stages of processing to begin at different times depending on sentence length and placement of key words (Kaan, 2007). However, single words have been used in ERP task switching paradigms successfully (e.g. Dreisbach et al., 2007). A more ecologically valid and forensically applicable study could be conducted using a mock crime scenario and incentives for success. One possibility for this study would be to use valid word cues to signal question type for the upcoming trial (i.e. crime, and non-crime). Following these cues, the question could be presented and responded to. However, the ERP response could be time-locked to the cue, rather than to the question, and may result in anticipatory task set reconfiguration processes, and a switch positivity, as well as switch costs (sentences would be balanced between repeat and switch trials, equating reading time). However, as it is possible that anticipatory task set reconfiguration is not necessary to complete a task switch, it would need to be determined whether this process was automatic, or could be consciously altered or inhibited. An alternative possibility could be to design image stimuli in a way that they could represent yes-no questions about a crime. Suspects could be required to learn these image-question representations before completing a test. This method would be more comparable to the current study, and it may result in detecting more reliable processes, which are *necessary* to occur when task, or sincerity switching.

Combining ERPs with response time measures may mean countermeasures used to manipulate one measure are revealed by the other. For example, if suspects were to attempt to mentally engage in another sort of task switching during a lie detector's repeat trials (which could cause switch-repeat ERP differences to reduce), this difficult multitasking may be picked up in markedly slowed response times. If participants were to use countermeasures to attempt to equate their response times on repeat and switch trials, sincerity switching may still be picked up in ERP measures. Future research would be needed to determine whether undetectable countermeasures could be developed for use against a sincerity switching lie detector.

Combining the method of detecting sincerity switching markers with established methods of lie detection could also achieve greater accuracy. It is plausible that switch-related processes occur during the GKT. However, these are not directly measured nor separated, as denial responses to *both* probes and foils may involve switching from the previous 'denial task'. This could be another path for future research.

Summary and Conclusions

The present study investigated whether markers of task switching (switch costs and ERP amplitude differences), similar to those found in a traditional task switching paradigm, could be found in a paradigm in which participants switched between lying and telling the truth. The behavioural results indicate that, as hypothesised, switch costs occurred in both traditional and sincerity switching paradigms. This finding is consistent with the task switching literature, and suggests that task switching processes may be involved when sincerity switching. Electrophysiological differences were found at the midline parietal electrode site (Pz), although their direction was contrary to that hypothesised: a negativity, rather than a positivity was observed. There is evidence this may reflect a switch negativity, as the negativity found in the sincerity switching paradigm occurred at a similar latency to the traditional paradigm, and their scalp distributions appear similar to those of switch negativities found the literature.

As task switching markers were found when participants switched between lying and telling the truth, these markers have potential to be used to develop a new method of lie detection. Future research is needed to address the limitations of the current study, to replicate findings, and to expand on the area of task switching in a deception context. Much research would also be needed to outline limitations, success rates, and best practices of using a sincerity switching lie detector before this method could be used in a forensic setting. However, results of the current study suggest that further research is warranted.

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List of Appendices

Appendix A

Ethics Approval Letter

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05 May 2017

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Division of Psychology
University of Tasmania

Student Researcher: Sarah Williams

Sent via email

Dear Dr Matthews

Re: MINIMAL RISK ETHICS APPLICATION APPROVAL
Ethics Ref: **H0016351 - Task Switching and Deception Detection: A Pilot Study**

We are pleased to advise that acting on a mandate from the Tasmania Social Sciences HREC, the Chair of the committee considered and approved the above project on 05 May 2017.

This approval constitutes ethical clearance by the Tasmania Social Sciences Human Research Ethics Committee. The decision and authority to commence the associated research may be dependent on factors beyond the remit of the ethics review process. For example, your research may need ethics clearance from other organisations or review by your research governance coordinator or Head of Department. It is your responsibility to find out if the approval of other bodies or authorities is required. It is recommended that the proposed research should not commence until you have satisfied these requirements.

Please note that this approval is for four years and is conditional upon receipt of an annual Progress Report. Ethics approval for this project will lapse if a Progress Report is not submitted.

The following conditions apply to this approval. Failure to abide by these conditions may result in suspension or discontinuation of approval.

1. It is the responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval, to ensure the project is conducted as approved by the Ethics Committee, and to notify the Committee if any investigators are added to, or cease involvement with, the project.

2. Complaints: If any complaints are received or ethical issues arise during the course of the project, investigators should advise the Executive Officer of the Ethics Committee on 03 6226 7479 or human.ethics@utas.edu.au.

3. Incidents or adverse effects: Investigators should notify the Ethics Committee immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.

4. Amendments to Project: Modifications to the project must not proceed until approval is obtained from the Ethics Committee. Please submit an Amendment Form (available on our website) to notify the Ethics Committee of the proposed modifications.

5. Annual Report: Continued approval for this project is dependent on the submission of a Progress Report by the anniversary date of your approval. You will be sent a courtesy reminder closer to this date. **Failure to submit a Progress Report will mean that ethics approval for this project will lapse.**

6. Final Report: A Final Report and a copy of any published material arising from the project, either in full or abstract, must be provided at the end of the project.

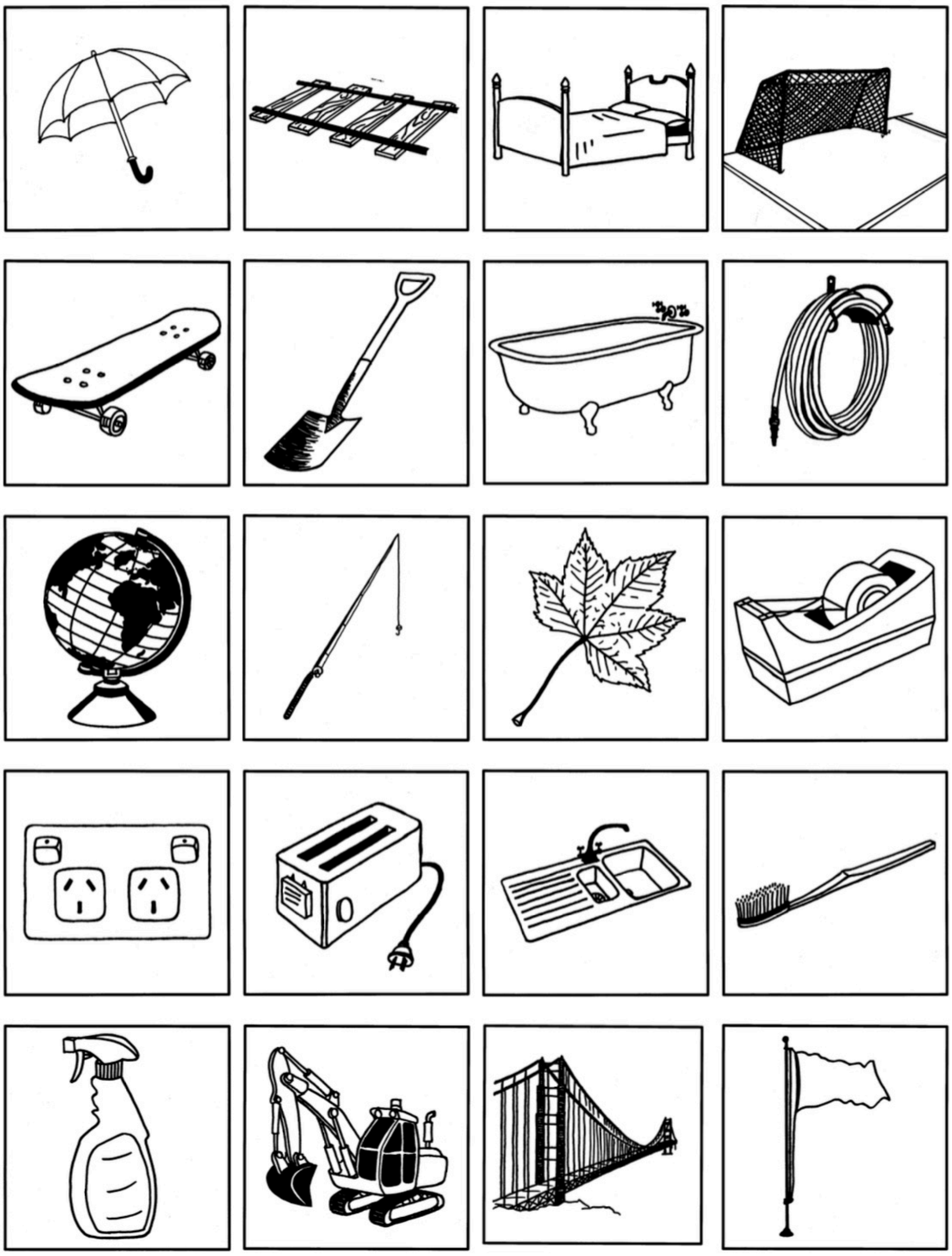
Yours sincerely

Katherine Shaw
Executive Officer
Tasmania Social Sciences HREC

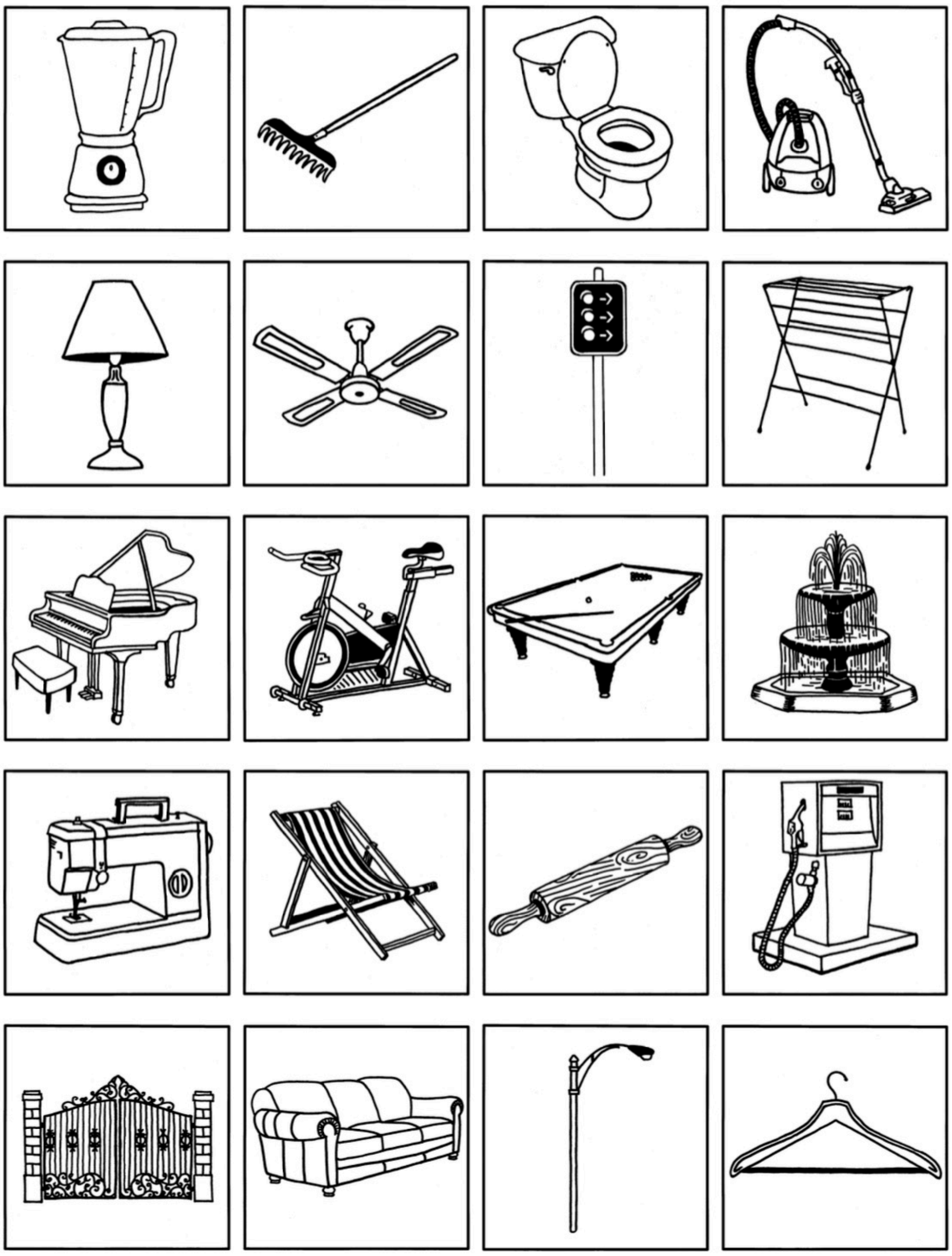
Appendix B

Stimuli Lists

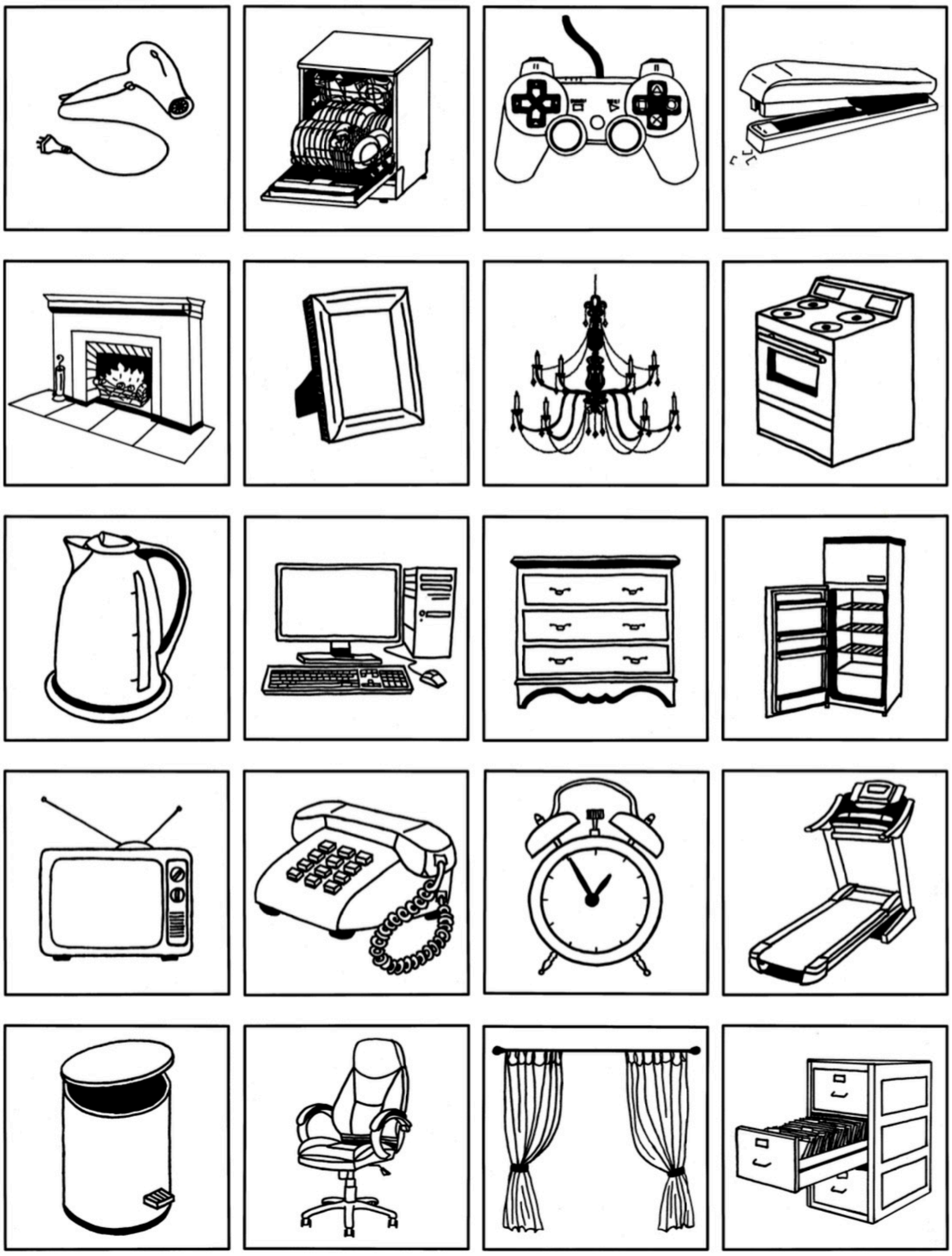
List A



Other objects that will be presented during this task



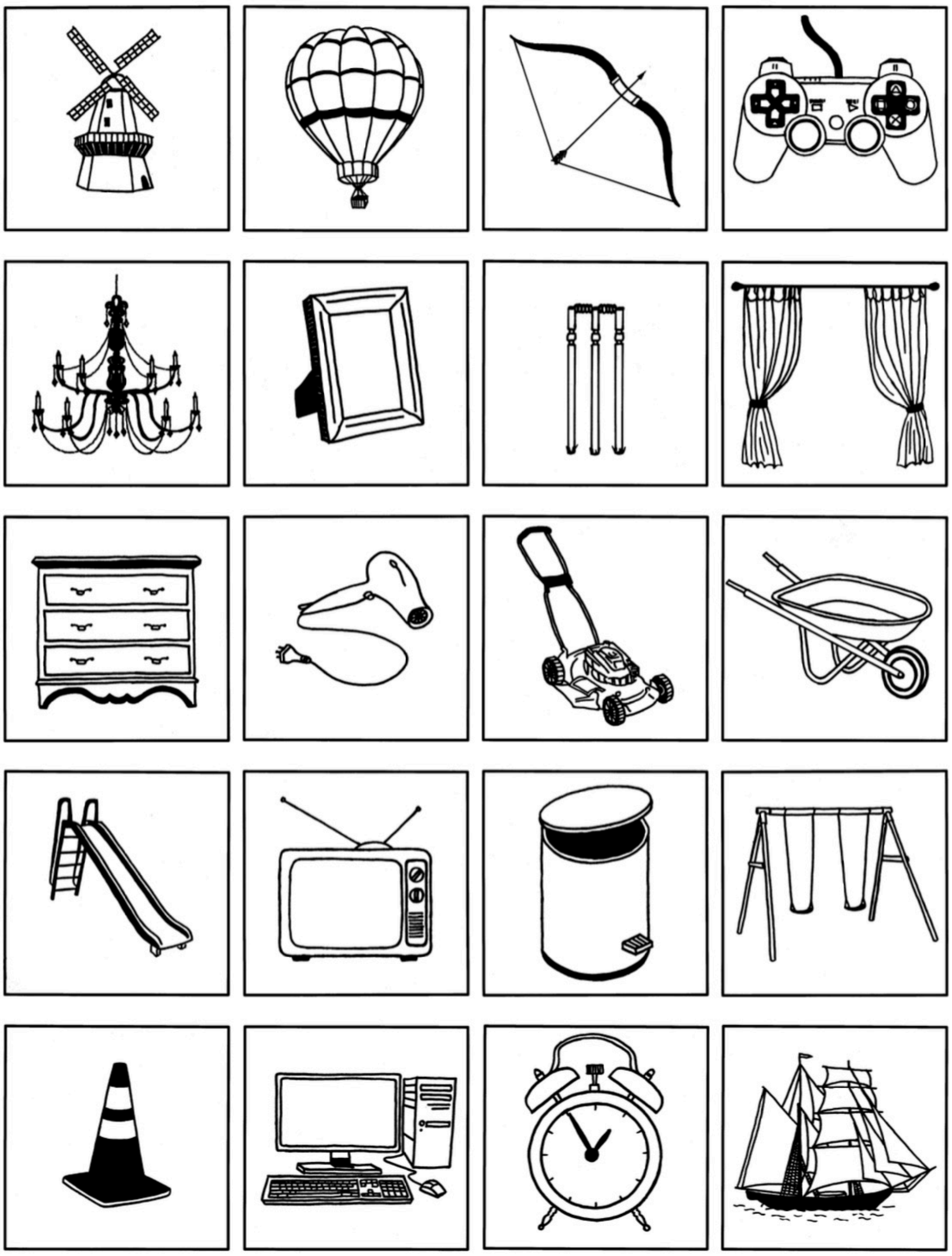
Indoors Objects



Outdoors Objects

Facing Left

NOT Facing Left



Appendix C

Previous-to-Current Trial Types and Counts

Table C1

Preceding and Current Trial Types in the Sincerity Switching Paradigm

Target on Previous Trial	Target on Current Trial	Count
Green A	Green A	10
Green B	Green B	10
Green A	Green B	10
Green B	Green A	10
Blue A	Blue A	10
Blue B	Blue B	10
Blue A	Blue B	10
Blue B	Blue A	10
Green A	Blue A	10
Green B	Blue B	10
Green A	Blue B	10
Green B	Blue A	10
Blue A	Green A	10
Blue B	Green B	10
Blue A	Green B	10
Blue B	Green A	10
‘Yes’ response	‘Yes’ response	40
‘No’ response	‘No’ response	40
‘Yes’ response	‘No’ response	40
‘No’ response	‘Yes’ response	40
Trial Type		
Repeat trials		80
Switch/Change trials		80
Total		160

Notes. Trial type counts were held constant in both Pure and Mixed blocks. A = targets from List A. B = targets from the ‘Other Objects’ list.

Table C2

Preceding and Current Trial Types in the Traditional Task Switching Paradigm

Target on Previous Trial	Target on Current Trial	Count
Green L	Green L	10
Green N	Green N	10
Green L	Green N	10
Green N	Green L	10
Blue I (L)	Blue I (L)	10
Blue O (N)	Blue O (N)	10
Blue I(L)	Blue O (N)	10
Blue O (N)	Blue I (L)	10
Green L	Blue I (L)	10
Green N	Blue O (N)	10
Green L	Blue O (N)	10
Green N	Blue I (L)	10
Blue I (L)	Green L	10
Blue O (N)	Green N	10
Blue I (L)	Green N	10
Blue O (N)	Green L	10
'Yes' response	'Yes' response	40
'No' response	'No' response	40
'Yes' response	'No' response	40
'No' response	'Yes' response	40
Trial Type		
Incongruent		80
Congruent		80
Repeat trials		80
Switch/Change trials		80
Total		160

Notes. Congruent and incongruent trials evenly distributed across all trial types. L = Left Facing. N = Not Left Facing. I = Indoors. O = Outdoors. For the colour counterbalanced mixed block, trial counts were the same as above but 'Green' is substituted for 'Blue' and 'Blue' for 'Green'. Pure Block trial types are displayed in brackets if different from mixed block.

Appendix D

Task Questionnaire

SUDS Scale and Task Questionnaire Participant ID __________ Task _________

How distressed did you feel during the task you just completed?

(Please circle a number)

0 1 2 3 4 5 6 7 8 9 10

Low distress Moderate distress High distress

How difficult did you find the task you just completed?

(Please circle a number)

0 1 2 3 4 5 6 7 8 9 10

Very Easy Moderate Very Difficult

Do you have any comments on the task you just completed (were there any strategies that you used to complete the task, was there anything that made it particularly difficult)?

Appendix E

Participant Information Sheet

Lie Detection and Brain Activity

This information sheet is for individuals who have been invited to participate in this research study.

Invitation

You are invited to participate in a research project investigating the brain processes involved in telling a lie and telling the truth. Sarah Williams (student) is conducting the study as part of her Honours degree in Psychology, under the supervision of Dr Allison Matthews (Lecturer, School of Medicine). This study will be conducted in the Cognitive Neuroscience Laboratory at the University of Tasmania.

What is the purpose of this study?

There are many different methods of lie detection police may use during investigations, from analysis of nonverbal behaviour to polygraph testing. However, none of these methods have a success rate high enough to be considered dependable. The aim of this study is to investigate differences in brain activity when lying and telling the truth. This information may inform the development of more accurate lie detectors, reducing the number of falsely accused suspects and incorrectly exonerated criminals.

Why have I been invited to participate?

You have been invited to take part in this study based on your results to a telephone screening questionnaire or online screening survey. Individuals are invited to participate if they are right handed, aged between 18 and 35 years, are not bilingual, and have normal or corrected-to-normal vision and hearing. Also, they have no recent history of physical, neurological or mental health problems, nor recent history of drug/heavy alcohol use (recreational or prescribed).

Your participation in this study is entirely voluntary and there are no consequences if you decide not to participate, or if you withdraw from the study. You are free to withdraw from the study at any time.

What will I be asked to do?

The experiment will be conducted in a single session, which will take approximately 3 hours, in the Cognitive Neuroscience Laboratory at the University of Tasmania. During this session you will be asked to complete some questionnaires, memorise some images of objects, be quizzed on these objects to make sure you remember them, and complete four tasks on computer. Before these computer tasks, you will be fitted with an electrode cap to measure your brain activity while you complete the tasks. At the end of the experiment you will be debriefed and thanked for your time.

Are there any possible benefits from participation in this study?

There is no direct benefit to you from participating in this research study. This research aims to contribute to scientific knowledge in the area of lie detection, with the hope of developing a more reliable lie detector than those currently in use. If you are a first year psychology student, you will receive three hours course credit for your participation.

Participant Information Sheet

Are there any possible risks from participation in this study?
If you have sensitive skin, there is a small possibility that you may have a slight skin reaction from the electrode preparation materials. You are advised to reconsider participation if you believe your skin may react. The equipment used to measure EEG activity may feel a little uncomfortable, however it is not painful and there are no specific risks associated with measuring brain activity. In some trials during the tasks you will be asked to lie. This has the potential to cause a small amount of anxiety. If you become distressed, you are free to discontinue the study at any time, without providing a reason.

What if I change my mind during or after the study?
You are free to withdraw at any time during the study, without consequence and you do not need to provide a reason. After the study, you may also choose to withdraw your data by contacting Sarah Williams (sa.williams@utas.edu.au), at any time prior to August 31st, 2017.

What will happen to the information when this study is over?
All data will be treated in a confidential manner. Collected data will be identified by a unique code, rather than by name, and a separate data file which links this code to your name and contact details will be stored in a password protected excel file. Only the researchers involved in this study will have access to this linking file. All data will be kept on a secure computer server or in locked storage at the School of Psychology. It will be stored for five years, and then be destroyed by secure deletion from the server, or by secure shredding.

How will the results of the study be published?
If the data from this study is published, the data will be reported as grouped data and no participant will be personally identifiable. If you would like access to these findings, please contact Sarah Williams (sa.williams@utas.edu.au) after the 31st November 2017.

What if I have questions about this study?
If you would like more information about this study, please contact Sarah Williams (sa.williams@utas.edu.au) or Dr Allison Matthews (Allison.Matthews@utas.edu.au).

This study has been approved by the Tasmanian Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive Officer of the HREC (Tasmania) Network on +61 3 6226 6254 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Ethics reference number H0016351.

This information sheet is for you to keep. If you would like to consent to being involved in this study, please sign the consent form provided.

Appendix F

Participant Consent Form

Participant Consent Form

Lie Detection and Brain Activity

1. I agree to take part in the research study named above.
2. I have read and understood the Information Sheet for this study.
3. The nature and possible effects of the study have been explained to me.
4. I understand that the study involves:
   - Attending one testing session of approximately three hours, during which my brain activity will be recorded
   - Completing some short questionnaires, memorising a list of objects and being tested on this list
   - Completing four computer-based tasks involving pressing buttons in response to visual stimuli
5. I understand that participation involves the risk of slight skin irritation if I have sensitive skin. I also understand that in some cases during the tasks, I will be asked to lie, and this has the potential to cause some anxiety.
6. I understand that all research data will be securely stored on the University of Tasmania premises for five years from the publication of the study results, and will then be destroyed by shredding and deletion of computer files.
7. Any questions that I have asked have been answered to my satisfaction.
8. I understand that the researcher(s) will maintain confidentiality and that any information I supply to the researcher(s) will be used only for the purposes of the research.
9. I understand that the results of the study will be published so that I cannot be identified as a participant.
10. I understand that my participation is voluntary and that I may withdraw at any time without any effect. If I so wish, I may request that any data I have supplied be withdrawn from the research until 31st August 2017.

Participant's name: ____

Participant's signature: ______________________Date: ____________

Statement by Investigator

☐ I have explained the project and the implications of participation in it to this volunteer and I believe that the consent is informed and that he/she understands the implications of participation.

If the Investigator has not had an opportunity to talk to participants prior to them participating, the following must be ticked.

☐ The participant has received the Information Sheet where my details have been provided so participants have had the opportunity to contact me prior to consenting to participate in this project.

Investigator's name: ____

Investigator's signature: ______________________Date: ____________

Appendix G

Experimental Session Screening Questionnaire

Experimental Session Questionnaire Participant ID ___________

Experimental Session Questionnaire

Date ___/___/___

1. Have you abstained from illicit drugs since the screening interview?

   ☐ **Criteria fulfilled**

If criterion has not been fulfilled, do not record any information on this sheet

2. Have you consumed alcohol within the last 24 hours?

   yes / no

3. How many cups of coffee (or other caffeinated drinks/products) have you consumed today?

   ____

   if >0: how many hours since your last caffeinated drink?

   ____

4. Have you had any tobacco or nicotine products today?

   yes / no

   if yes: how many cigarettes/nicotine products have you had today?

   ____

   if yes: how many hours has it been since your last cigarette or nicotine product?

   ____

5. Have you consumed any medications in the past week (or since the screening interview)?

   yes / no

   if yes, please detail:

Medication	Number of occasions taken	Time since last taken	Estimated dose

Are you an undergraduate psychology student? **yes / no**